ALTERNATIVES TO RIVER SAND

A SUSTAINABLE APPROACH

SEMINAR DOCUMENT

organised by

ICI-KBC

Friday,
13th December 2013

in association with

KSPCB

Dr. R. Nagendra
Chairman, ICI-KBC

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Vice-Chairman, ICI-KBC

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Editor - in - Chief

ICI-KBC

KSPCB

ONE DAY SEMINAR

on

ALTERNATIVES TO RIVER SAND

A SUSTAINABLE APPROACH

Friday, 13th December 2013

Venue :

Karnataka State Pollution Control Board,

Parisara Bhavana, Tejasvi Hall

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Dr. R. Nagendra

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EDITORIAL

River sand is a widely used construction material all over the world, especially in the production of concrete and cement-sand mortar. Various Government, Non Governmental organisations and Research Institutes are striving to identify alternative materials to supplement river sand. There is a strong need for research on river sand substitutes for concrete production and cement sand mortar production. The research should aim to identify suitable river sand substitutes for practical applications in the local construction industry and also focus on formulating practical solutions for using river sand substitutes. The development of standards / specifications and incorporating in the BIS codes will reduce the pressure on using river sand. The standards and codal specifications will assist to select and use the alternatives by the various stake holders. Quality certification of the alternate aggregates and quality certification of the concrete manufacturing process plays a vital role in ensuring the durability of the concrete.

Indian concrete Institute, Karnataka Bangalore centre is constantly working in this direction to disseminate knowledge to all stake holders. This one day seminar organised in association with Karnataka State Pollution Control Board is one such activity.

I have tried to collect and compile the information from various sources on alternatives to river sand and produced in this document. Researchers, Academicians, Consultants and Material Testing Institutes have contributed their experiences and knowledge for this document. The sand manufactures and sand equipment manufacturers also have shared their information on latest technologies in this field.

Some of the articles are sourced from Hand books/ Journals, Conference Proceedings and open web sources for the purpose of disseminating knowledge. The copyrights are with the respective organisation and acknowledged at appropriate place.

On behalf of ICI-KBC, KSPCB and the organizers, I thank all the contributors for their timely support. References are made to various standards/codes of BIS etc, my thanks to all these organisations.

I am sure this document will be useful, if used with further readings and references without sacrificing the quality, standards and specifications in achieving a sustainable growth.

Prof. Aswath M.U.
Editor-in-Chief

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ABOUT US
ICI-KBC

Indian Concrete Institute - Karnataka Bangalore Centre
www.icikbcbangalore.org Email:icikbc@gmail.com

- ICI was born on 7th September 1982, with Head Quarter in Chennai.
- It has 30 centers with more than 10000 members spread across the country.
- ICI is having more than 35 ICI-Student chapters across the country.
- ICI-Karnataka Bangalore center was started in the year 1984 and it is successfully being run by an able adoptive and progressive managing committees since then.
- ICI -Karnataka (Bangalore) Centre is one of the active centres,which conducts several programs every year.
- ICI-KBC has a membership of over 600 with over members in Bangalore city and member ship is growing progressively day by day.
- ICI-KBC is having 6 student chapters affiliated to it.
    1. SIT-TUMKUR
    2. UVCE-BANGALORE
    3. MVJ COLLEGE OF ENGINEERING-BANGALORE
    4. R.V.COLLEGE OF ENGINEERING-BANGALORE
    5. GLOBAL ACADEMY OF TECHNOLOGY-BANGALORE
    6. JNN COLLEGE OF ENGINEERING-SHIMOGA

Objectives:

- Promote growth of concrete construction and its sub-specialization
- To disseminate information and train personnel by organizing seminars/Conferences/workshops.
- Training programs for fellow members/students and corporate.
- Collaborate with national / international agencies.
- Identify R & D problems of practical relevance.,
- Arrange National and International Workshops, Conferences, Seminars, Deminars and Exhibitions.
- Arrange annual lecture series on selected topics of relevance to Concrete Constructions.

- To identify and recognize outstanding construction and outstanding performers in the field of concrete technology/construction.

Important Events and Programs from ICI -Karnataka Bangalore Centre.

- Monthly technical lectures, Endowment Lectures, National Workshops and Conferences.
- ICI-KBC was the first to organize ICI-IWC (Innovative World of Concrete) in 1993,ICI ACECON in 2000.
- ICI-KBC is the first centre among all the centres of ICI in India to start Concrete Panorama and Deminars at Bangalore in the year 2009.
- Training Modules on Concrete and Concrete Technology for various organizations and Institutions, These programs are conducted throughout the year to cater for the specific needs of the organizations concerned.

Concrete Days Celebrations:

- Indian Concrete Institute-Karnataka Bangalore centre celebrates concrete Day on 7 th September every year. This event is celebrated in a grand and befitting manner.
- Every year during the Concrete Day Celebrations ICI-KBC in association with Ultratech Cements Ltd recognizes outstanding and innovative structures built using concrete as main construction material and also identify and honour an individual who has worked for the cause of Concrete and rendered significant contributions to the research, development and application of concrete.
- The two prestigious awards instituted and given away during the Concrete Day Celebrations are:

  ICI-KBC –Ultratech Endowment Award for outstanding Concrete Engineer of Karnataka.

  ICI-KBC Birla Super Endowment Award for Outstanding Concrete Structure of Karnataka.

The following Managing Committees are instrumental

in keeping the flag of ICI-KBC fly very high since its inception in 1984

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Indian Concrete Institute - Karnataka Bangalore Centre (ICI - KBC)

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15.	Dr. R. Nagendra	Ms. Sapna Devendra	2013-

The Group Photo of the Chairmans and Secretaries takenduring the ICI-KBC silver jubilee celebrations along with management committee members of ICI-KBC (2008-2011).During the Function all the chairman and Secretaries were honoured for their contributionsfor the Growth and Development of ICI-KBC

Message by ICI President

I congratulate Indian Concrete Institute – Karnataka Bangalore Centre for organizing one day seminar on ' Alternatives to river sand – a sustainable approach' along with Karnataka State Pollution Control Board.

The 12th Five year Plan of India is specially focussed on growth of infrastructure facility. Concrete will be single most construction material that would be used in these endeavours. Sand is one of the essential ingredients of concrete. Shortage of river sand is already widespread, extending from parts of Kerala and Karnataka to those of Maharastra and Gujrat.

In this context, the topic of the seminar is highly relevant and I wish the conference a grand success.

Prof. S. Saraswati
President
Indian Concrete Institute.

Message by Chairman, KSPCB

It is a matter of joy to wish the one day seminar on`ALTERNATIVES TO RIVER SAND - A SUSTAINABLE APPROACH' jointly organised by Indian Concrete Institute - Karnataka Bangalore Centre and Karnataka State Pollution Control Board (KSPCB).

KSPCB has been undertaking many initiatives to make best use of the solid waste that is being generated by various industries in Karnataka. We have been encouraging industries to use the by-products like Fly-ash, Blast Furnace Slags, Ferro-alloy and other metallurgical slags, By product gypsum, Lime sludge (phos- pho chalk, paper and sugar sludge), Chromium sludge, Red mud, Pulp & Paper, Granite sludge, foundry sand in various construction activities.

Being a statutory body KSPCB is mandated to monitor the waste management by industries. The alternatives that will be discussed in the seminar will definitely provide the industries a win-win situation where in apart from managing the waste, they can even have significant revenue generated.

I wish all the stakeholders will participate in the seminar and make it a huge success.

Dr. VAMAN ACHAYRA
Chairman

Message by ICI Vice President (South)

Construction industry is currently passing through a critical phase facing several constraints. These include severe shortage of trained labour, muted growth of infrastructure projects, high inflation, lower growth of the manufacturing and service sectors among others. Concrete being a versatile material in construction, an added challenge is the availability and affordability of aggregates, which constitute 85 to 90 % in concrete. River sand, which was the natural choice of construction industry has become scarce due to its over- exploitation and increasing environmental concerns. National Green Tribunal which has taken cognisance of this has enforced severe restrictions on sand mining from river beds and the relevant laws for obtaining license have been made very tight. In view of this, there is an urgent need to look at various alternatives to sand. Though several alternatives are available (manufactured sand, slag sand, pond ash as sand, C & D waste converted into aggregates), various stake holders in the construction industry are debating their advantages and limitations compared with river sand, apart from the feasibility of producing them on commercial scale.

Recognising this predicament of the industry, the Indian Concrete Institute (Karnataka – Bangalore Centre) has organized this Seminar on **Alternatives to sand – a sustainable approach** *in association with the Karnataka State Pollution Control Board. With well known experts sharing their experience on the problems faced and solutions available, I am sure that this event will provide rich insights and show the way forward.*

On behalf of ICI, construction industry and on my own behalf, I congratulate the ICI – KBC and KSPCB for taking this initiative for the benefit of all stake holders in the construction industry, academia and students. I wish the program a grand success.

Dr. V. Ramachandra

Vice President – South

From ICI-KBC Chairman's Desk

River sand is a widely used construction material all over the world in the production of concrete and cement-sand mortar. With natural sand deposits drying up, there is an acute need for a product that matches the properties of natural sand in concrete In the last 15 years, it has become clear that the availability of good quality natural sand is decreasing. With a few local exceptions, it seems to be a global trend. Existing natural sand deposits are being emptied at the same rate as urbanization and new deposits are located either underground, too close to already built-up areas or too far away from the areas where it is needed, that is, the towns and cities where the manufacturers of concrete are located. Environmental concerns are also being raised against uncontrolled extraction of natural sand. The arguments are mostly in regards to protecting riverbeds against erosion and the importance of having natural sand as a filter for ground water. This is the situation for the construction industry today and most will agree that it will not change dramatically in the foreseeable future. There is a need to look for alternatives to river sand without scarifying durability of the concrete/mortar. It is in this context Indian Concrete Institute, Karnataka, Bangalore Centre is conducting one day seminar on "Alternatives to River Sand" in association with Karnataka State Pollution Control Board for the benefit of Civil Engineers, Architects, Builders and RMC Companies.

In the seminar presentations on various alternatives to river sand such as Crushed Stone Sand popularly known as manufactured sand, Slag Sand, Pond Ash, Sand from construction and demolition wastes etc is being made. A document consisting of articles from eminent researchers, practitioners on various alternatives of river sand is being published.

Dr. R. Nagendra

Chairman, ICI-KBC

From ICI-KBC Vice-Chairman's Desk

At the outset I am very much happy that Indian concrete Institute-Karnataka Bengaluru centre in association with Karnataka state pollution control Board,Bangalore is conducting the one day seminar on " Alternatives to river sand –a sustainable Approach" on 13 th dec 2013 and coming out with a state –of- the -art seminar document on Alternatives to river sand on the occasion.

This document is first of its kind in India on the above subject covering all types of alternatives to river sand ,manufacturing process ,manufacturing equipments and usage of these alternatives replacing natural river sand partially or fully. We at ICI-KBC sincerely hope that this seminar document will become a reference book for all the stake holders in the construction industry who want to use alternative materials to replace natural river sand as replacement for a sustainable tomorrow and protect our environment for the future generations.

L.R.Manjunatha

Vice Chairman –ICI-KBC

From ICI-KBC Secretary's Desk

Dear all, Indian Concrete Institute, Bangalore Centre with all your support has again bagged the best centre award among 30 centres all across India. It's becoming more and more vibrant with more interactive members and associates. All the events have made their own Impact on the construction industry. Here all members believe "In teaching others we teach ourselves – Traditional proverb" and duly involve themselves and motivate others too to get involved, our regular Technical lectures are its result. As all of us know "Knowledge increases by sharing but not by saving - Kamari aka Lyrikal" our dedicated training programs to all the segments of construction industry has thus become more attractive.As Irish proverb says "There is no knowledge without unity " all the ICI members come together to organise its landmark event Deminar every year, which not only show cases theoretical knowledge but also gives practical demonstrationto its audiences. And many more such programs organised by ICI has taken place and will be done ahead because we here in ICI trust on "There is no wealth like knowledge, and no poverty like ignorance- Buddha".

So lets soon meet up during our upcoming Deminar during early 2014 with most recent and innovative topics to share with you all so that we are not" In vain have you acquired knowledge if you have not imparted it to others - Deuteronomy Rabbah"

Wishing you all happy new year 2014.

Ms. Sapna Devendra

Secretary– South, ICI-KBC

Alternatives to River Sand - A Global Perspective

Raj Pillai

River sand is a precious material and should be used very judisiously.

Unfortunately in our country this is not the case and the outcome of this is multifold. At one side there is demand supply gap leading to usage of deleterious material in the name of river sand on the other hand rampant sand mining is causing havoc in the form of flash floods (the recent one being in Utharakhand), drying up of underground water table, rivers changing course etc.

Bangalore alone needs in excess of one million ton of sand per month and in case of Karnataka state the sand requirement will be around 40 million ton per year. This kind of demand is impossible to meet and thus leads to many questions which need answers.

However the irony is sand or fine aggregate is essential component of construction.

Keeping above paradox in mind and taking a leaf out of best global practices, following recommendations are made to have a Sustainable scientific approach to meet the challenge.

1. River flow inflow assessment and optimal sand mining.

The quantum of sand mined from rivers is several folds more then what flows down and accumulate into river beds. This situation creates a serious environmental threat. The impact can be broadly classified as follow

a. Off site impact.
b. On site impact.

The onsite impact can be further classified as

1. Excavation impact
2. Water supply impact.

The impacts associated with excavation are channel bed lowering, migration of excavation pits, undermining of structures, bank collapse, caving, bank erosion, valley widening and channel instability.

The water supply impacts are

1. Reduced ground water recharge to local aquifers.
2. Reduction in storage of water for people and live stock.
3. Contamination of water by oil and gasoline.
4. Conflicts between locals and miners.
5. Enlargement of river mouths and coastal inlet leading to saline water intrusions.
6. Destruction of aquatic and riparian habits trough large change in channel morphology.
7. Impact also includes bed degradation. Bed coarsening, lowered water table near the stream bed and change in soil structure.

All above changes dramatically changes the socio economic conditions of river basins and were cause of collapse of major civilizations.

The sand deposition eventually leads to reduction in conveyance capacity of river leading to floods. Proper dredging of sand keeps the bed at desired level.

The sand inflow can be calculated by using analytical method called bed load transportation model. The most commonly used method is Mayers- Peter formulae. The method uses sample of sand from different critical locations flow data and other river characteristics. The value of different parameters in the model are calculated using lab and field tests, the model can take into account past many years for better average result. An average of rate is taken as the daily rate of sediment transport for different months. The sand inflow is calculated which is then converted into truck load of sand per day.

By using above methodology, the river bed can attain a steady bed profile leading to much advantage.

2. Prepration of Comprehensive Mineral planning Policy in line with advanced countries-

A mineral planning is essential for judicial use of natural resources. The government of UK after consultation with industry and other interested bodies publish their aim for aggregate industry as Mineral Planning Guide 6(MPG6). The guide outlines the general policy regarding guidance to mineral planning authorities and operators on how to ensure a steady and adequate supply of aggregates both coarse and fine, keeping in mind environmental and socio economical considerations.

The objectives of sustainable development for mineral planning for England are set out as follow.

1. To conserve minerals as far as possible whilst ensuring an adequate supply to meet the needs of society for minerals.
2. To minimize production of waste and to encourage efficient use of materials including appropriate use of high quality materials and recycling of wastes.
3. To encourage sensitive working practices during mineral extraction and to preserve or enhance the overall quality of the environment once extraction is ceased.
4. To protect areas of designated landscape or nature conservation from development, other than in exceptional circumstances where it has been demonstrated that development is in public interest.

We can work out a similar plan meeting the needs of our country.

3. USE OF ALTERNATIVES TO RIVER SAND

1. The obvious alternative is manufactured sand which is widely used all over the world and is a common material in neighboring states like kerla where use of natural sand is banned. The only bottle neck in manufacturing sand is availability of long term quarries at reasonable distance from major cities. If the government takes initiatives on this front, many players would definitely like to enter this field which would also stream line steady flow of revenue to government in the form of royalty from limited players.

2. Use of other materials like marine dredged sand, construction waste and demolition material, Blast furnace slag and steel slag, slate waste, power station ash.

An incentive can be provided if such alternative materials are used.

Acknowledgement

1. River sand inflow assessment and optional sand policy document by Binoy , shiney and Kichu paul.
2. Government of UK mineral planning policy.

The author is a Member of 'Institute of Quarrying' UK and has completed Doncaster Asisted Private Study" a two year course on quarrying and crushing from Doncaster university UK.

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River Sand Substitutes
- An Overview

Aswath M U

INTRODUCTION

The construction industry is growing with major trust on infrastructure and the demand for sand is also increasing. The overuse of river sand for construction has many undesirable environmental and social consequences. The natural sand deposits are depleting and illegal sand mining is becoming uncontrollable issue. In-stream sand mining has become a common practice and resulted in a mushrooming of river sand mining activities which have given rise to various problems that require urgent action by the authorities. These include river bank erosion, river bed degradation, river buffer zone encroachment and deterioration of river water quality and groundwater availability.

Sand is required for development of the country, but at the same time the threats posed due to sand mining cannot be ignored. Uncontrolled illicit river sand mining creates a level of damage to rivers that are ecologically irreversible even in the long run; an urgent and sustainable solution is now needed for the affected rivers and communities. Hence decisive steps have to be taken and alternate solutions found for sand mining, without disturbing the environment.

Damage to banks and riverbed (Photo Courtesy : Ranjith Ratnayake)

Mechanized mining

Damage to bank, infrastructure and change of river course

(Photo Courtesy : Ranjith Ratnayake)

THE DEMAND AND PROTESTS

As there is huge demand for the sand in the construction industry the river sand resources are depleting. The illegal mining of natural resources is creating major problems. Environmentalists are protesting against mining of these natural resources not only in India but all over the world. The regulating authorities such as The National Green Tribunal, Ministry of Environment and Forests, the State Environment Impact Assessment Authority (SEIAA) and the Pollution control Boards etc are restraining sand mining without any license/permit or environmental clearance from river beds across the country.

Awaaz Foundation and BNHS(Bombay Natural History Society) created awareness against coastal sand mining for the first time in a national or international forum at the UN Convention on Biodiversity, Conference of Parties 11 in Hyderabad India in October 2012

- Take Action to End Global Beach Sand Mining!
- We urge you to become part of the movement by submitting the following petition:
- The petition to end beach sand mining is a non-political effort.

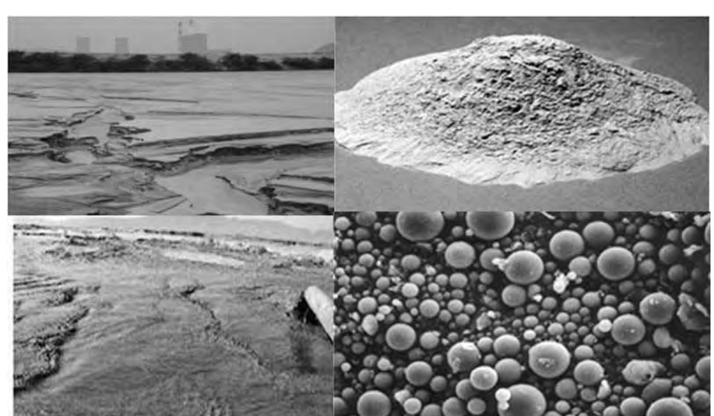
The NGT served the order to stop mining activities in all states :

Initially, the bench banned illegal sand mining on the beds and banks of rivers Yamuna, Ganga, Hindon, Chambal, Gomti, amongst others, but later modified its order saying the issue of illegally removing sand has nationwide implications.

RIVER SAND SUBSTITUTES

Sand Researchers world over are in continuous search for the alternatives to sand. Fine aggregate is one of the important constituents of concrete and mortar in construction industry.. River sand is becoming a scarce material. Sand mining from our rivers has become objectionably excessive. It has now reached a stage where it is killing all our rivers day by day. So sand mining has to be discouraged so as to save the rivers. As natural sand deposits become depleted near some areas of metropolitan growth, the use of alternatives to sands as a replacement fine aggregate in concrete is receiving increased attention. As a solution for this, various alternatives are explored and used in many parts of the world. Some of them are:

- Manufactured Sand(M Sand),
- Processed Quarry Dust,
- Processed Crushed Rock Fines(CRF),
- Offshore Sand,
- Dune Sand,
- Washed Soil (Filtered Sand),
- Fly Ash/ Bottom Ash/Pond Ash
- Slag Sand,
- Copper Slag Sand,
- Construction Demolition Waste,
- Powdered Glass
- Aluminum saw mill waste
- Granite Fines/Slurry and Many More.



FLY ASH/ BOTTOM ASH/POND ASH

Pond ash is the by-product of thermal power plants, which is considered as a waste material and its disposal is a major problem from an environmental point of view and also it requires a lot of disposal areas. There are three types of ash produced by thermal power plants, viz. (1) fly ash, (2) bottom ash, and (3) pond ash. Fly ash is collected by mechanical or electrostatic precipitators from the flue gases of power plant; whereas, bottom ash is collected from the bottom of the boilers. When these two types of ash, mixed together, are transported in the form of slurry and stored in the lagoons, the deposit is called pond ash. More detailed study papers are available in this document elsewhere.

COPPER SLAG

Addition of slag in concrete increases the density thereby the self weight of the concrete.

- The results of compression & split-tensile test indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of additions
- The recommended percentage replacement of sand by copper slag is 40%.
- The studies revealed that the addition of slag does not pave way for leaching of harmful elements like Copper (Cu) and Iron (Fe) present in slag in concrete. Thus, it does not pose any environmental problem.

ALTERNATIVES FOR RIVER SAND: THE POTENTIAL OF OFFSHORE SAND: [14]

The overuse of river sand for construction has various undesirable social and ecological consequences. As a solution for this, various alternatives such as offshore sand, quarry dust (or manufactured sand), dune sand and washed soil have been considered. This research focuses on using offshore sand as the most viable alternative for river sand.

The purpose of using offshore sand is because the environmental and ecological impact from extracting the sand from 15 meters below sea level is minuscule. Using beach sand is not a viable solution due to the impacts it has, such coastal erosion, salt water intrusion into rivers and collapsing of river banks. It has been found that the costs for pumping and dredging will be considerably lower than for river sand. Transportation costs should not exceed that of river sand. With the intention of exploring this new challenge of using offshore sand as a viable replacement for river sand, Prof. Priyan Dias, along with his colleagues Prof. Anura Nanayakkara and Prabath Seneviratna, embarked on this research. The main objectives were to review the prevailing literature regarding the concept, to characterize the sands by observing the various properties such as the grading, the shell and chloride content while observing the draining and rain effects on the chloride content and finally to study the corrosion performance of the reinforced concrete made using offshore sands.

The literary review revealed that most of the documentation regarding the usage of offshore sand is from UK, whereas some European countries have also recorded the practice. It should be noted that this is different from using sand deposits - which when deployed in the Middle East have resulted in accelerated corrosion due to the high chloride contents resulting from the long term exposure to salt spray. Also, resorting to methods such as using sea water for batching will increase chloride contents. Hence they are to be avoided at all costs.

The research methodology involved building a 2 meter column of sand and observing the effects of natural drainage and simulated rain. Even as little as 320 mm of simulated rain (the highest average monthly rainfall in Colombo) has reduced the chloride levels well below the acceptable levels. Furthermore, using seawater within the derived acceptable limits has not increased the rate of natural corrosion in concrete with embedded steel. The accelerated-corrosion performance has been impressive, as it was no different to a chloride-free control mixture. On the other hand, using a mixture of seawater saturated sand (i.e. without allowing drainage or natural washing) has resulted in much higher corrosion.

CONCLUSIONS:

- The need of the hour is in striking a balance between growing needs of construction industry and environmental concerns to preserve river beds amid excessive sand mining.
- The government should come out with a policy for sand mining and use of alternatives
- Changing specifications of the Bureau of Indian Standards (BIS) to ensure substitutes of sand can be used by builders across the country.
- Alternatives to sand like m-Sand (manufactured sand), copper slag, powdered glass and recycled construction waste etc which are increasingly being used in many EU nations, Singapore and the US should be encouraged in India.
- Environmentalists across the globe are in favour of such locally viable alternatives.
- Research should be encouraged on durability of concrete with different alternatives.

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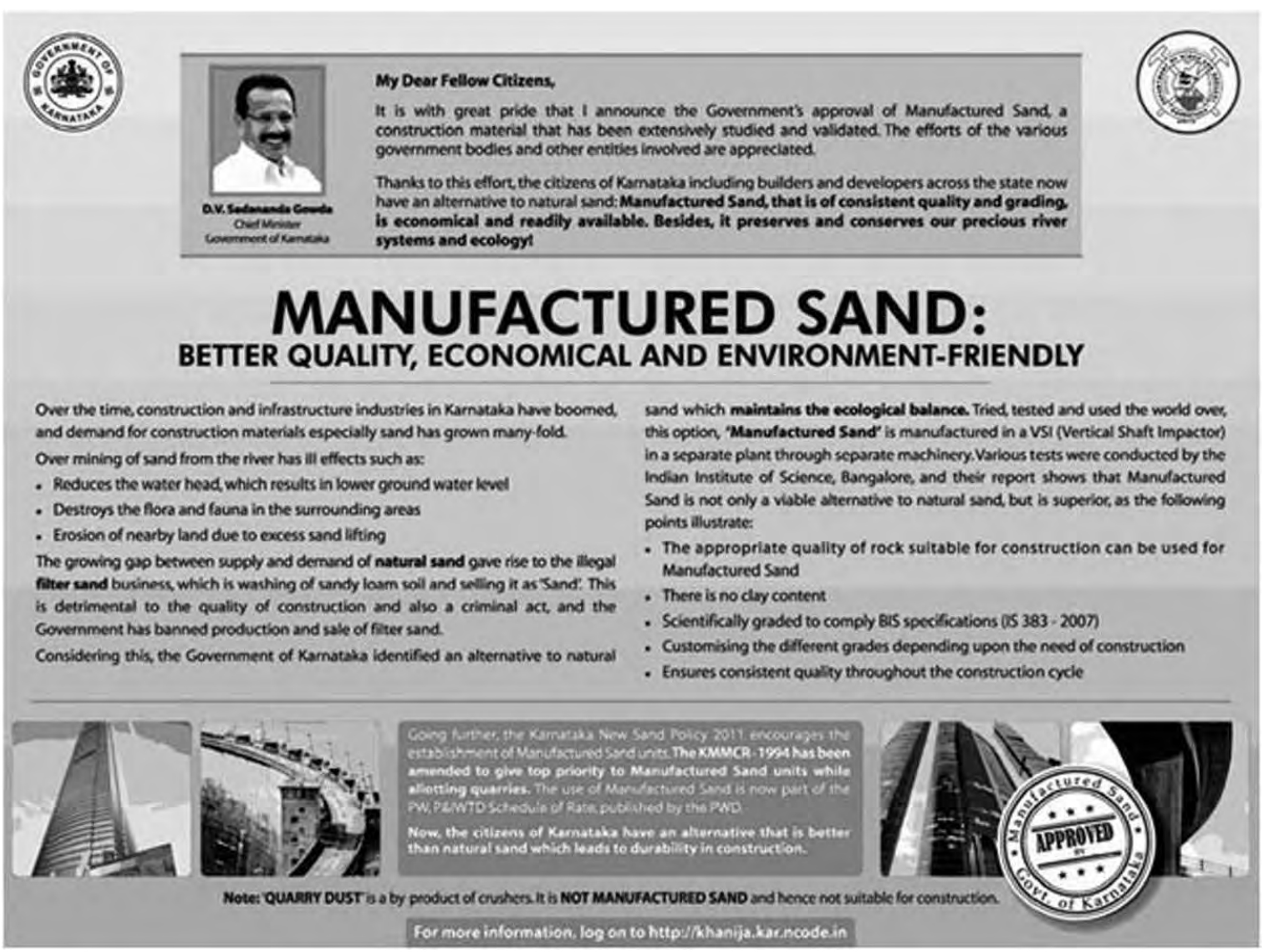


Technical Specifications for Fine Aggregates

Aswath M U

INTRODUCTION

Sand is mainly used for the preparation of mortar and concrete. It is also required to manufacture the building blocks. The standard terminology used for sand is fine aggregate. We all know that Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand is silica (silicon dioxide, or Si O2), usually in the form of quartz. Fine aggregate (Sand and/or crushed stone) are less than 4.75 mm in size. Fine aggregate content is usually 35% to 45% by mass or volume of total aggregate.

Infrastructure development in India is accelerating. The construction industry has contributed an estimated 670,778 crores to the national GDP in 2011-12 (a share of around 8%).[1] But the construction industry is facing serious challenge. We have to address the performance and delivery capacity of construction industry to implement the projects on time with quality and safety. Sand is one of the major materials required for the construction industry but need to address the environmental issues at the same time. The many uses of Sand require a significant dredging industry, raising environmental concerns over fish depletion, landslides, and flooding. Countries such as China, Indonesia, Malaysia and Cambodia ban sand exports, citing these issues as a major factor. [2]

The natural sand and gravel resources are being depleted in India and in most parts of the world. The trend is towards using more of crushed and manufactured aggregates as well as recycled material. Other industrial by products like fly ash, pond ash, slag and copper slag are also finding place in the partial replacement for aggregates. Conflicts due to land use for quarrying are common all over the country and the need for long term planning is a pressing social, economical and political issue. The energy consumption for aggregate production is relatively small, compared to the energy consumption for the production of concrete, but the transport of aggregates from quarry to customer has large energy impact and is increasing in general. [3]

THE DEMAND

Due to the growth of construction industry and major infrastructure projects, there is a huge demand for sand as a building material. This leads to acute shortage of river sand for the construction purpose.

Sand mining is a practice that is used to extract sand, mainly through an open pit. However, sand is also mined from beaches, inland dunes and dredged from ocean beds and river beds. It is often used in manufacturing as an abrasive, for example, and it is used to make concrete. As communities grow, construction requires less wood and more concrete, leading to a demand for low-cost sand. Sand is also used to replace eroded coastline. [1] Sand mining is a practice that is becoming an environmental issue in India. Environmentalists have raised public awareness of illegal sand mining in India.

The impacts of sand mining on the environment are many: reduces the water head, so less percolation of rain water in ground, which result in lower ground water level; erosion of nearby land due to excess sand lifting; disturbance due to digging for sand & lifting, destroys the flora & fauna in surrounding areas.[3]

The greed of man and the demand for sand is responsible for the illegal sand mining. It has become a major issue throughout the country. There are many conflicts between the politicians, bureaucrats and sand suppliers due to illegal mining.

TECHNICAL SPECIFICATIONS FOR SAND

Aggregates shall comply with the requirements of IS 383-1970(Reaffirmed 2002). As far as possible, preference shall be given to natural aggregates. Other types of aggregates such as slag and crushed over burnt brick or tile, which may be found suitable with regard to strength, durability of concrete and freedom from harmful effects may be used for plain concrete members, but such aggregates should not contain more than 0.5 percent of sulphates as SO, and should not absorb more than 10 percent of their own mass of water.

IS 383-1970(Reaffirmed 2002) classifies sand in to;

Natural Sand - Fine aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies,

Crushed Stone Sand- Fine aggregate produced by crushing hard stone; and

Crushed Gravel Sand - Fine aggregate produced by crushing natural gravel.

QUALITY OF AGGREGATES

Aggregates shall consist of naturally occurring (crushed or uncrushed) stones, gravel and sand or combination thereof. They shall be hard, strong, dense, durable, clear and free from veins and adherent coating; and free from injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As far as possible, flaky, scoriaceous and elongated pieces should be avoided.

Deleterious Materials -Aggregates shall not contain any harmful material such as pyrites, coal, lignite, mica, shale or similar laminated material, clay, alkali, soft fragments, sea shells and organic impurities in such quantity as to affect the strength or durability of the concrete.

Aggregates to be used for reinforced concrete shall not contain any material liable to attack the steel reinforcement. Aggregates which are chemically reactive with alkalies of cement are harmful as cracking of concrete may take place. *[Note: Aggregates petrographically similar to known reactive types or aggregates which, on the basis of service history or laboratory experiments, are suspected to have reactive tendency should be avoided or used only with cements of low alkalies {not more than 0.6 percent as sodium oxide (Na_2O)} after detailed laboratory studies. use of pozzolanic cement and certain pozzolanic admixtures may be helpful in controlling alkali aggregate reaction.*]

Limits of Deleterious Materials: The maximum quantity of deleterious materials shall not exceed the limits specified in Table 1 when tested in accordance with IS: 2386-1963. However, the engineer-in-charge at his discretion may relax some of the limits as a result of-some further tests and evidence of satisfactory performance of the aggregates.

Aggregate Crushing Value: The aggregate crushing value, when determined in accordance with IS: 2386 (Part IV)-1963 shall not exceed 45 percent for aggregate used for concrete other than for wearing surfaces, and 30 percent for concrete for wearing surfaces, such as runways, roads and pavements.

Aggregates Impact Value: As an alternative, the aggregate impact value may be determined in accordance with the method specified in IS: 2386 (Part IV)-1963. The aggregate impact value shall not exceed 45 percent by weight for aggregates used for concrete other than for wearing surfaces and 30 percent by weight for concrete for wearing surfaces, such as runways, roads and pavements.

Aggregate Abrasion Value: Unless otherwise agreed to between the purchaser and the supplier, the abrasion value of aggregates, when tested in accordance with the method specified in IS: 2386 (Part IV)-1963 using Los Angeles machine, shall not exceed the following values:

a) For aggregates to be used in concrete for wearing surfaces: 30 percent

b) For aggregates to be used in other concrete: 50 percent

Soundness of Aggregate: For concrete liable to be exposed, the action of frost, coarse and fine aggregates shall pass a sodium or magnesium sulphate accelerated soundness test specified in IS: 2386 (Part V)-1963, the limits being set by agreement between the purchaser and the supplier, except that aggregates failing in the accelerated soundness test may be used if they pass a specified freezing and thawing test satisfactory to the user. [Note: - As a general guide, it may be taken that the average loss of weight after 5 cycles shall not exceed the following:

a) For fine aggregate: 10 percent when tested with sodium sulphate ($Na_2\ SO_4$), and 15 percent when tested with magnesium sulphate ($Mg\ SO_4$)

b) For coarse aggregate 12 percent when tested with sodium sulphate ($Na_2\ SO_4$), and 18 percent when tested with magnesium sulphate ($Mg\ SO_4$)

TABLE 1 LIMITS OF DELETERIOUS MATERIALS

IS:383-1970 Reaffirmed 2002 Clause 3.2.1 TABLE 1 LIMITS OF DELETERIOUS MATERIALS						
SL. NO.	DELETERIOUS SUBSTANCE	METHOD OF TEST	FINE AGGREGATE PERCENTAGE BY WEIGHT, Max		COARSE AGGREGATE PERCENTAGE BY WEIGHT, Max	
			Uncrushed	Crushed	Uncrushed	Crushed
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Coal and Lignite	IS: 2386 (Part II)-1963	1.00	1.00	1.00	1.00
ii)	Clay lumps	IS: 2386 (Part II)-1963	1.00	1.00	1.00	1.00
iii)	Materials finer than 75-µ IS Sieve	IS: 2386 (Part I)-1963	3.00	15.00	3.00	3.00
iv)	Soft fragments	IS: 2386 (Part II)-1963	----	----	3.00	----
v)	Shale	IS: 2386 (Part II)-1963	1.00	----	----	----
vi)	Total of percentages of all deleterious materials (Except mica) including Sl. No. (i) to (v) for Col 4,6,7 and Sl. No. (i) and (ii) for Col 5 only.	----	5.00	2.00	5.00	5.00

NOTE 1 - The presence of mica in the fine aggregate has been found to reduce considerably the durability and compressive strength of concrete and further investigations are underway to determine the extent of the deleterious effect of mica. It is advisable, therefore, to investigate the mica content of fine aggregate and make suitable allowances for the possible reduction in the strength of concrete or mortar.

NOTE 2 - The aggregate shall not contain harmful organic impurities [tested in accordance with IS: 2386 (Part II) - I963] in sufficient quantities to affect adversely the strength or durability of concrete. A fine aggregate which fails in the test organic impurities may be used, provided that, when tested for the effect of organic impurities on the strength of mortar, the relative strength at 7 and 28 days, reported accordance with 7 of IS : 2386 (Part VI)-1963 is not less than 95 percent. NOTE 2- The aggregate shall not contain harmful organic impurities [tested in accordance with IS: 2386 (Part II) - I963] in sufficient quantities to affect adversely the strength or durability of concrete. A fine aggregate which fails in the test organic impurities may be used, provided that, when tested for the effect of organic impurities on the strength of mortar, the relative strength at 7 and 28 days, reported accordance with 7 of IS : 2386 (Part VI)-1963 is not less than 95 percent.

TABLE-6 PARTICLE SHAPE

IS:383-1970 Reaffirmed 1997 Clause C-3.2			
CLASSIFICATION	DESCRIPTION	ILLUSTRATION OF CHARACTERISTIC SPECIMENS	EXAMPLE
(1)	(2)	(3)	(4)
Rounded	Fully water worn or completely shaped by attrition	Fig. 1	River or seashore gravels; desert, seashore and windblown sands
Irregularly or partly rounded	Naturally irregular, or partly shaped by attrition, and having round edges	Fig. 2	Pit sands and gravels; land or dug flints; cuboid rock
Angular	Possessing well- defined edges formed at the inter-section of roughly planar faces	Fig. 3	Crushed rocks of all types; tullus; screes
Flaky	Material, usually angular, of which the thickness is small relatively to width and/or length	Fig. 4	Laminated rocks

SIZE AND GRADING OF AGGREGATES

IS 383 defines Fine Aggregates as aggregate most of which passes 4.75-mm IS Sieve and contains only so much coarser material as permitted in cl.4.3. [Cl. 4.3 Fine Aggregates -The grading of fine aggregates, when determined as described in IS: 2386 (Part I)-1963 shall be within the limits given in Table 4 and shall be described as fine aggregates, Grading Zones I, II, III and IV. Where the grading falls outside the limits of any particular grading zone of sieves other than 600-micron IS Sieve by a total amount not exceeding 5 percent, it shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing the 600-micron IS Sieve or to percentage passing any other sieve size on the coarse limit of Grading Zone I or the finer limit of Grading Zone IV.]

TABLE 3 FINE AGGREGATES

IS:383-1970 Reaffirmed 1997 Clause 4.3) TABLE 4 FINE AGGREGATES				
IS SIEVE DESIGNATION	PERCENTAGE PASSING FOR			
	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10 mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
600 micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

NOTE 1- For crushed stone sands, the permissible limit on 150-micron IS Sieve is increased to 20 percent. This does not affect the 5 percent allowance permitted in 4.3 applying to other sieve sizes.

NOTE 2 - Fine aggregate complying with the requirements of any grading zone in this table is suitable for concrete but the quality of concrete produced will depend upon a number of factors including proportions.

NOTE 3 - Where concrete of high strength and good durability is required, fine aggregate conforming to any one of the four grading zones may be used, but the concrete mix should be properly designed. As the fine aggregate grading becomes progressively finer, that is, from Grading Zones I to IV, the ratio of fine aggregate to coarse aggregate should be progressively reduced. The most suitable fine to coarse ratio to be used for any particular mix will, however, depend upon the actual grading, particle shape and surface texture of both fine and coarse aggregates.

NOTE 4- It is recommended that fine aggregate conforming to Grading Zone IV should not be used in reinforced concrete unless tests have been made to ascertain the suitability of proposed mix proportions.

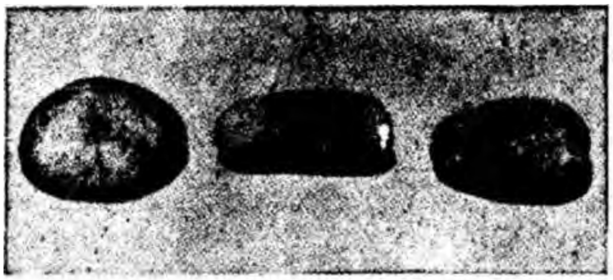


Fig.1 PARTICLE SHAPE:ROUNDED

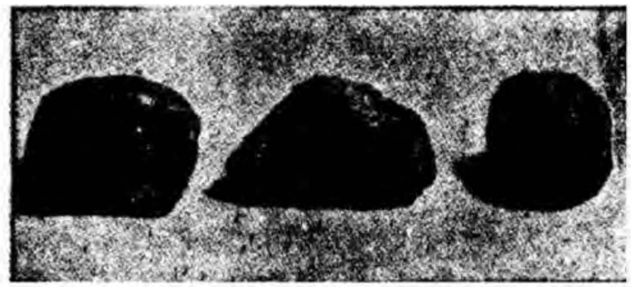


Fig. 2 PARTICLE SHAPE:IRREGULAR

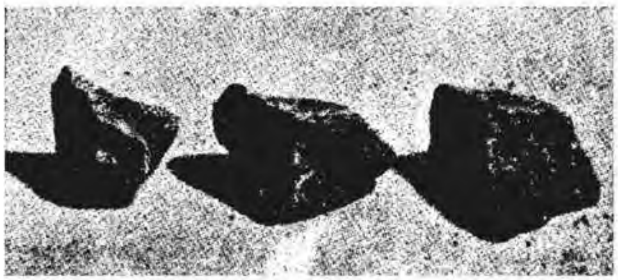


Fig.3 PARTICLE SHAPE:ANGULAR

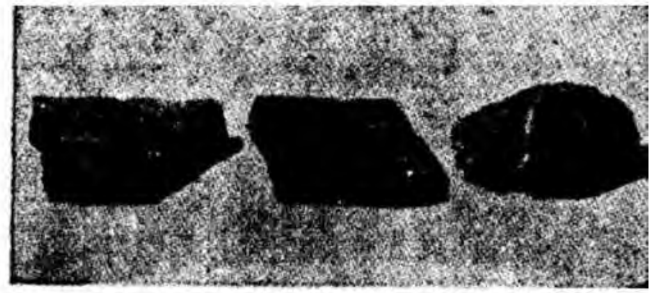


Fig.4 PARTICLE SHAPE:FLAKY

SIGNIFICANCE OF GRADING [4]

IS Sieve Designation	Percentage passing by weight Grading			
	Zone - I (CourseSand)	Zone - II Most Suitable /Desirable	Zone - III	Zone - IV (Fine Sand)
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 µm	15-34	33-59	60-79	80-100
300 µm	5-20	8-30	12-40	15-50
150 µm	0-10	0-10	0-10	0-15
Fineness Modulus	4.0-2.71	3.37-2.10	2.78-1.71	2.25-1.35

Fine-Aggregate Grading Limits

Fine-Aggregate Grading Limits

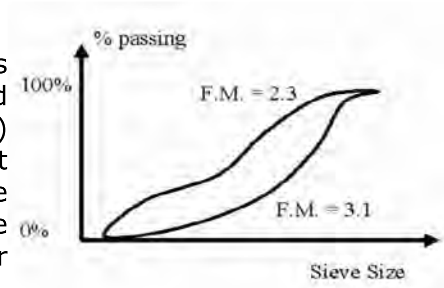
The percentage passing 600µm sieve will decide the zone of the sand: Zone-I Coarse Sand; Zone-II; Zone-III and Zone-IV Fine Sand. Grading Limits can also be represented through a graph of sieve size on the x-axis and % passing on the Y-axis (Semi log sheet).

Fineness Modulus (FM): The result of aggregate sieve analysis is expressed by a number called Fineness Modulus. It is obtained by adding the sum of the cumulative percentages by mass of a sample aggregate retained on each of a specified series of sieves and dividing the sum by 100. The specified sieves are: 150 µm (No. 100), 300 µm (No. 50), 600 µm (No. 30), 1.18 mm (No. 16), 2.36 mm (No. 8), 4.75 mm (No. 4), 9.5 mm , 19.0 mm , 37.5 mm , 75 m , and 150 mm.

Sieve Size	Percentage of individual fraction retained by mass	Percentage passing by mass	Cumulative percentage retained by mass
10 mm	0	100	0
4.75 mm	2	98	2
2.36 mm	13	85	15
1.18 mm	20	65	35
600 µm	20	45	55
300 µm	24	21	79
150 µm	18	3	97
Pan	3	0	–
TOTAL	100		283

Results of Sieve Analysis and calculation of FM of Sand

Fineness modulus = 283 ÷ 100 = 2.83



FM is an index of fineness of an aggregate. The fineness modulus of the fine aggregate is required for mix design since sand gradation has the largest effect on workability. Fine sand (low FM) has much higher effect paste requirements for good workability. It is computed by adding the cumulative percentages of aggregate retained on each of the specified series of sieves, and dividing the sum by 100 [smallest size sieve: No. 100 (150 μm)]. The higher the FM, the coarser is the aggregate.

SAMPLING AND TESTING

Sampling: The method of sampling shall be in accordance with IS: 2430-1969. The amount of material required for each test shall be as specified in the relevant method of test given in IS: 2386 (Part I)-1963 to IS: 2386 (Part VIII)-1963.

Testing: All tests shall be carried out as described in IS: 2386 (Part I)-1963 to IS: 2386 (Part VIII)-1963. Unless otherwise stated in the enquiry or order, duplicate tests shall be made in all cases and the results of both tests reported.

INFORMATION TO BE FURNISHED BY THE SUPPLIER

Details of Information: When requested by the purchaser or his representative, the supplier shall provide the following particulars:

a) Source of supply, that is, precise location of source from where the materials were obtained;
b) Trade group of principal rock type present
c) Physical characteristics
d) Presence of reactive minerals; and
e) Service history, if any.
f) Subject to prior agreement, the supplier shall furnish such of the following additional information, when required by the purchaser:
g) Specific gravity,
h) Bulk density,
i) Moisture content,
j) Absorption value,
k) Aggregate crushing value or aggregate impact value,
l) Abrasion value,
m) Flakiness-index,
n) Elongation-index,
o) 3 Presence of deleterious materials,
p) Potential reactivity of aggregate, and
q) Soundness of aggregate,

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Suitability of Manufactured Sand (M-Sand) as fine aggregate in mortars and concrete

CSIC Project : CP 6597/0505/11-330 dated 5th July 2011

Project sponsored by : Department of Mines and Geology (Govt. of Karnataka), No. 49, Khanija Bhavan, Race Course Road, Bangalore - 560 001

Prof. B. V. Venkatarama Reddy

1. Introduction

Sand is used as fine aggregate in mortars and concrete. Natural river sand is the most preferred choice as a fine aggregate material. River sand is a product of natural weathering of rocks over a period of millions of years. It is mined from the river beds and sand mining has disastrous environmental consequences. River sand is becoming a scarce commodity and hence exploring alternatives to it has become imminent. Rock crushed to the required grain size distribution is termed as manufactured sand (M-sand). In order to arrive at the required grain size distribution the coarser stone aggregates are crushed in a special rock crusher and some of the crushed material is washed to remove fines. This investigation is an attempt to evaluate the characteristics of mortars and concrete using M-sand as fine aggregate. For the purposes of comparison characteristics of mortar and concrete with river sand has also been explored.

2. Scope and details of the study

Major objective of the study was to examine the suitability of M-sand as fine aggregate in mortars and concrete. Apart from characterising the properties of M-sand, tests were performed on the mortars and concrete using M-sand as well as natural river sand. One M-sand sample (supplied by the Department of Mines and Geology) and one natural river sand sample were used in the investigations. The following tests were performed.

1. Characteristics of M-sand; grain size distribution, pH and chemical composition
2. Mortar and masonry characteristics using M-sand and river sand
    a. Compressive strength of mortar
    b. Flow/workability
    c. Water retentivity
    d. Brick-mortar bond strength
    e. Compressive strength and stress-strain relationships for masonry
3. Concrete characteristics (two grades M20 and M30)
    a. Consistency
    b. Strength (compression and flexure)
    c. Shrinkage
    d. Bond (pull out test) strength
    e. Modulus: stress-strain relationships

The test programmes for mortars and concrete are highlighted in Tables 1 and 2 respectively. Two cement mortars (1:6 and 1:4, cement : sand by volume) were used and tested for strength, workability, water retentivity, masonry Compressive strength and masonry bond strength. Similarly, M20 and M30 grade concretes were tested for workability, shrinkage, strength, stress-strain characteristics and bond strength.

Table 1: Test programme for mortars using River sand and M-sand

Mortar and masonry property	1:6 cement mortar		1:4 cement mortar	
	River sand	M-sand	River sand	M-sand
1. W/C ratio versus mortar flow	√	√	√	√
2. Compressive strength at 85% and 100% flow	√	√	√	√
3. Water retentivity of mortars	√	√	√	√
4. Strength and stress-strain relationships for masonry	√	√	---	---
5. Flexure bond strength of masonry	√	√	---	---

Table 2: **Test programme for concrete using River sand and M-sand**

Concrete property	M20 grade concrete		M30 grade concrete	
	River sand	M-sand	River sand	M-sand
1. Consistency (slump)	√	√	√	√
2. Drying shrinkage	√	√	√	√
3. Compressive and flexure strength	√	√	√	√
4. Stress-strain relationships	√	√	---	---
5. Bond strength (pull out test)	√	√	---	---

3. Test methods and testing procedures

One rich mortar (1:4) and one commonly used mortar (1:6, M2 grade as per IS: 1905) were selected. Standard mix proportions for M20 and M30 grade concrete (commonly used) were selected following IS 456 code guidelines. Selected mix proportions for M20 and M30 grade concretes are 1:2:4 and 1: 1.66: 3.33 (cement: fine aggregate: coarse aggregate, by weight) respectively. The tests were performed using relevant standard codes of practice guidelines as mentioned below.

(a) Mortars

i) Flow characteristics: BS 4551 - 1980

ii) Water retentivity and Compressive strength: IS 2250 - 1981 (2000)

iii) Flexure bond strength: ASTM C1072

iv) Masonry Compressive strength: IS: 1905 - 1987 (2002)

(b) Concrete

i) Consistency of concrete: IS: 1199-1959(2004)

ii) Drying shrinkage: IS: 1199 - 1959 (2004)

iii) Stress-strain relationships: IS: 516 - 1959 (2004)

iv) Bond strength (pull out test): IS: 2770 (Part I) - 1967 (2002)

v) Compressive strength and flexure strength: IS: 516-1959 (2004)

4. Test results and discussion for mortars

(a) Characteristics of M-sand and natural river sand

Fig. 1 shows texture and shape of the M-sand and natural river sand particles. The grain size distribution curves of these sand samples are displayed in Fig. 2. Also, the upper and lower bound grain size distribution of curves of grading Zone-11 sand specified in IS 383 code are displayed. Table 3 gives details of the properties of both the types of sand. The following observations can be made from the grain size analysis results in Fig. 2 and the results given in Table 1 and Fig. 1.

1) The shape of the M-sand particles resembles with those of river sand particles. Flaky and elongated coarse particles are absent in the M-sand.

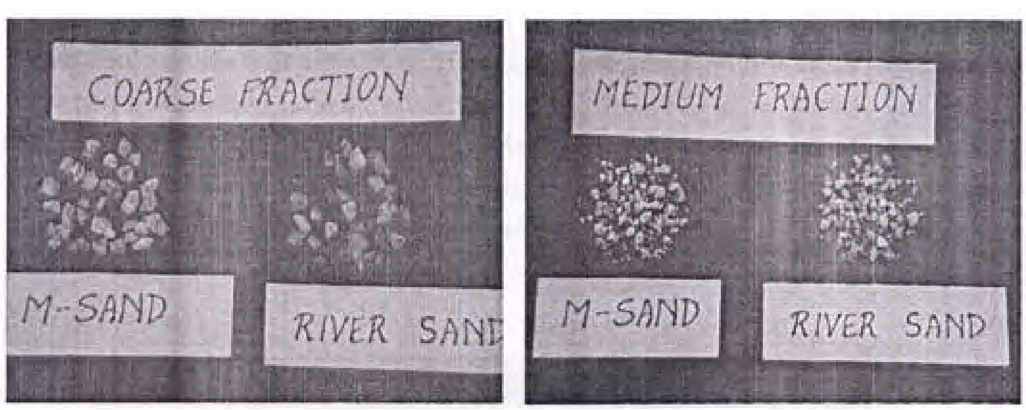
2) M-sand is well graded and falls within the limits of grading Zone-11 sand, grading limits specified in IS 383 code. Code allows 20% fines less than 150 microns for crushed stone sands. M-sand is devoid of clay size fraction and the fraction below 150 microns is about 18% (IS 3 83 code limit is 20%).

3) The specific gravity is 2.63 and 2.67 for M-sand and river sand respectively. Bulk densities of M-sand and river sand are 15.1 and 14.5 kN/m^3 respectively. Bulk density of M-sand is marginally higher than that of river sand. The pH of M-sand and river sand is 10.11 and 8.66 respectively.

4) M-sand contains typical rock forming minerals like quartz, feldspar, mica group of minerals, etc as revealed by X-ray diffraction (XRD) studies. Rock forming minerals like Quartz, feldspar, etc are basically inert in nature. Mica group consists of muscovite, biotite, boromuscovite, etc. The mica group of minerals are not interfering in the cement hydration and strength development in mortars and concrete.

Table 3 – Properties of M-sand and river sand

Properties	Type of Sand	
	M-sand	River sand
1. Textural composition (% by weight)		
Coarse Sand (4.75 – 2.00 mm)	28.1	6.6
Medium sand (2.00 – 0.425 mm)	44.8	73.6
Fine sand (0.425 – 0.075 mm)	27.1	19.8
2. Specific gravity	2.63	2.67
3. Bulk density (kN/m^3)	15.1	14.5
4. pH	10.11	8.66
5. Chemical composition of M-sand		
M-sand contrains elements like Si, Al, Ca, Mg, Na, K, Fe, etc.		



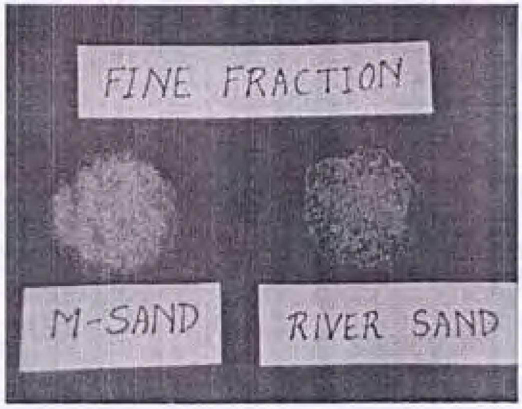


Fig. 1 – Texture of M-sand and natural river sand particles

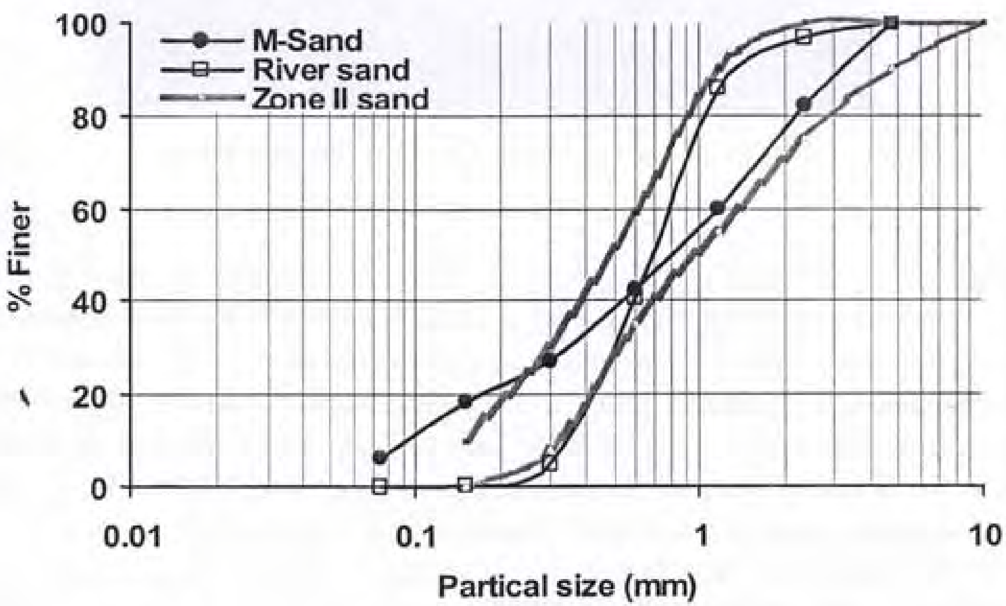


Fig. 2 – Grain size distribution curves of the M-sand and River sand

(b) Mortar characteristics using M-sand and river sand Flow/workability: Workability of the mortar should be such that it allows the mason to spread the mortar easily and adheres well to the masonry units. Mortar composition as well as water-cement ratio affects the workability. Workability of the fresh mortar can be measured by conducting a flow table test following the BS - 4551 code guidelines. Workability of fresh mortar is expressed as flow value. Fig. 3 shows mortar flow at 85% using M-sand in 1:6 cement mortar.

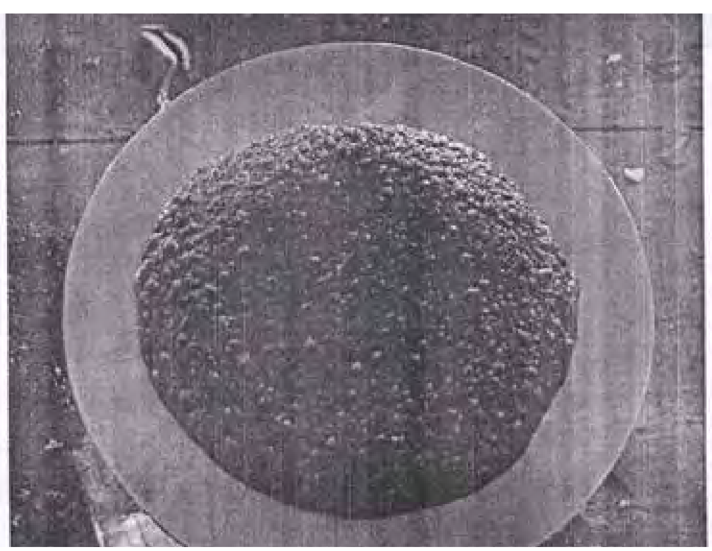


Fig. 3 - M-sand mortar at 85% flow (no segregation)

Flow tests were performed on the two types of mortars in order to establish relationships between flow and water-cement ratio. Figs. 4 and 5 show the flow versus water-cement ratio relationships for the 1:6 and 1:4 cement mortars respectively. Mortars with M-sand exhibit better flow characteristics. For example in case of 1:6 cement mortar, to achieve 100% flow the water cement ratio required is about 1.4 using M-sand and 1.75 using river sand. Similarly, for 1:4 cement mortar, it is 0.88 and 1.20. To achieve a given flow value, mortar with M-sand requires lower water-cement ratio. Lower water-cement ratio results in better characteristics for the mortars in hardened state. Flow values of different types of mortars from various construction sites were measured by Reddy and Gupta (2005) and they indicate a range of 85 - 100% for flow values.

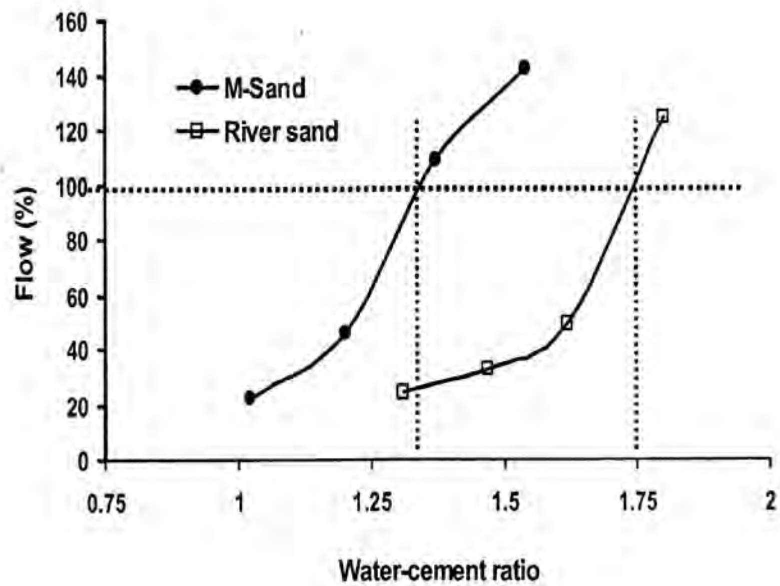


Fig. 4 – Flow versus water cement ratio for 1:6 cement mortar

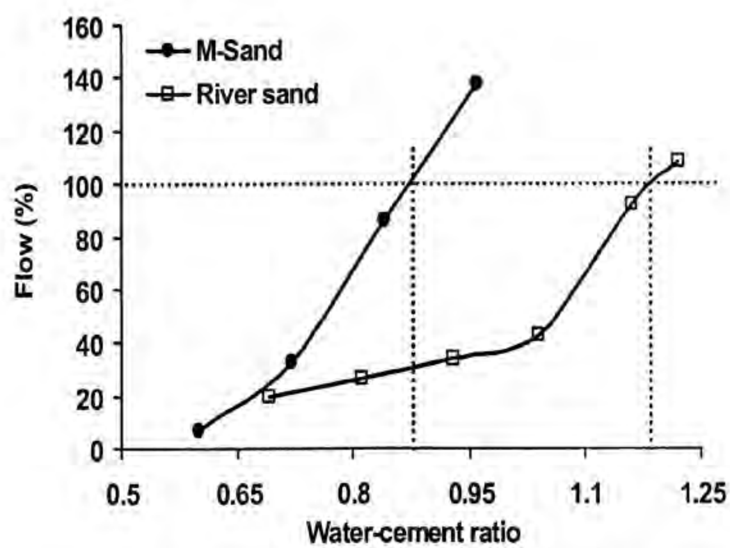


Fig. 4 – Flow versus water cement ratio for 1:4 cement mortar

Compressive strength: Compressive strength of mortars was assessed following the guidelines of IS 2250 code. Mortar flow (indicates workability) measurements carried out by Reddy and Gupta (2005) for a set masonry mortars collected from the different construction sites indicate a range of 85 - 100%. Therefore, the strength of the mortars was examined at two flow values of 85 and 100%. The water-cement ratio corresponding to the flow of 85 and 100% for the 1:4 and 1:6 cement mortars (using river sand and M-sand) is given in Table 4. For a given flow value there is considerable difference in the water-cement ratio of mortars using M-sand and river sand. Mortars with M-sand exhibit better flow and need lower water-cement ratio when compared to mortars with river sand.

Compressive strength values given in Table 4 represent mean of four specimens. Considerable increase in compressive strength of mortars between 7 and 28 days curing irrespective of flow value and sand type for both the mortars. There is doubling of mortar strength when M-sand is used instead of river sand. 28 day compressive strength of 1:6 and 1:4 cement mortars is about 8 and 16 MPa respectively for flow in the range of 85 - 100%. The results reveal that use ofM-sand produces higher strength for the mortars.

Table 4 - Compressive strength mortars

Mortar Proportion (by volume) Cement : sand	Flow (%)	Water – cement ratio		Compressive strength (MPa)			
				River sand		M-Sand	
		River sand	M-Sand	7 days	28 days	7 days	28 days
1:6	85	1.72	1.30	2.10	4.03	5.15	8.53
	100	1.75	1.34	1.96	3.82	4.88	8.19
1:4	85	1.13	0.84	2.84	7.35	12.89	15.96
	100	1.18	0.88	2.77	6.04	11.89	15.50

Water retentivity: Fresh mortar is sandwiched between bricks or blocks during the construction of masonry. Moisture gets sucked by the brick or block from the water rich mortar joint. The amount of water sucked by the brick or block from the mortar depends upon the porosity of the masonry unit, moisture content of the brick or block at the time of construction and the ability of the mortar to retain water against brick suction. Thus water retentivity can be defined as the ability of the mortar to retain water against the suction of the brick or block. Mortar has cementitious materials, thus initially it requires certain amount of water for the hydration process and development of strength. If the water loss from the mortar is large, this leads to low water-cement ratio in the mortar and improper hydration of the fresh mortar, thereby affecting the mortar characteristics and the bond development. Water retentivity of the mortar depends upon various factors like the mix proportion, water-cement ratio, type of cementitious binder, etc. Water retentivity of 1:6 and 1:4 cement mortars was examined using the procedure laid down in IS-2250 code.

Water retentivity values for 1:6 cement mortar using river sand and M-sand are 27.3% and 28.5% respectively. For 1:4 cement mortar it is 25.6% and 35.6% for river sand and M-sand respectively. Thus, water retentivity of mortars improves with the use of M-sand. Better water retentivity results in better strength and bond development.

Brick-mortar bond strength: There should be good bond between the mortar and the brick for the masonry to perform satisfactorily. Bond strength becomes significantly important when the , masonry has to resist tensile and shear stresses. Large number of parameters pertaining to bricks/blocks, mortars and construction practices influence the masonry bond strength. Surface characteristics of the masonry unit (pore size distribution, porosity, etc.), moisture content of the unit at the time of construction, absorption characteristics of the unit and mortar composition are some of the important characteristics influencing brick-mortar bond development. Brick-mortar bond strength can be measured by testing the masonry prism using a bond-wrench test set-up. ASTM C1072 code gives the procedure for bond-wrench test to evaluate the flexure bond strength of masonry prism. Fig. 5 shows the modified bond wrench set-up used in determining the flexure bond strength of masonry prism.

Flexure bond strength of masonry prisms using local burnt clay bricks and the 1:6 cement mortar with M-sand and river sand was determined. Six prisms were tested in each category to get the mean value of flexure bond strength. The flexure bond strength of masonry using 1:6 cement mortar (with 85% flow) was 0.06 MPa and 0.15 MPa for river sand and M-sand mortars respectively. The flexure bond strength of masonry prism has improved by 150% when M-sand was used instead of river sand in the 1:6 cement mortar.

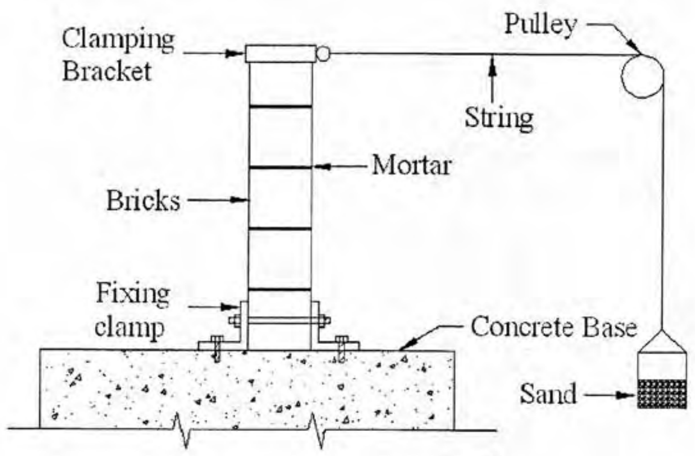
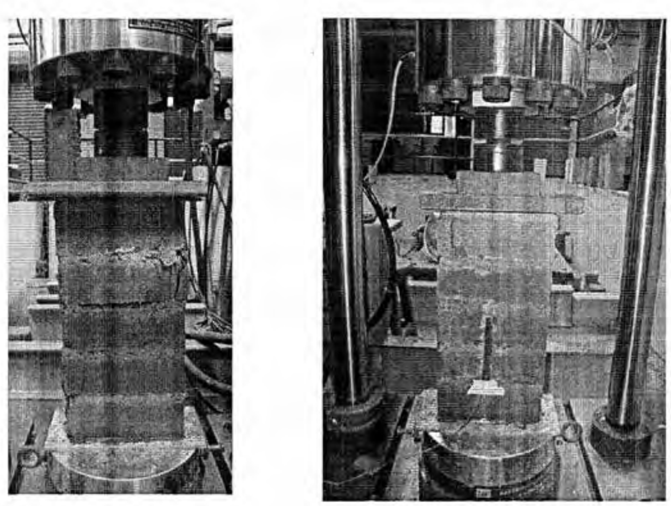


Fig. 5 – Flexure bond test set-up for masonry prism

Compressive strength of masonry: Compressive strength of masonry was examined by testing five brick high stack bonded masonry prisms. Prisms (size: 105 x 225 x 445 mm, having height to width ratio of 4.23) were prepared using burnt clay bricks having Compressive strength of 10.1 MPa (mean value) and using 1:6 cement mortar with river sand and M-sand. Compressive strength of the masonry prisms was 3.35 MPa and 4.38 MPa for mortar with river sand and M-sand respectively. These are the mean values of six prisms. Nearly 30% increase in masonry strength due to the use of mortar with M-sand was observed. Fig. 6a shows the masonry prism failure (typical vertical splitting cracks) using mortar with M-sand.



(a) Typical failure pattern (b) Prism with strain gauge

Fig. 6 – Stack bonded masonry prisms under compression tests

Stress-strain relationships for masonry: Stress-strain relationship was generated by testing stack bonded masonry prisms built using 1:6 cement mortar. The longitudinal strains were monitored through electrical resistance strain gauge as shown in Fig. 6b. The stress-strain curve for the masonry is shown in Fig. 7. The initial tangent modulus for the masonry is 1200 MPa and 500 MPa for the mortar with M-sand and river sand respectively. Modulus of masonry with M-sand is more than double that of modulus for masonry with river sand. The increase in modulus can be attributed to better bond between the mortar and the brick.

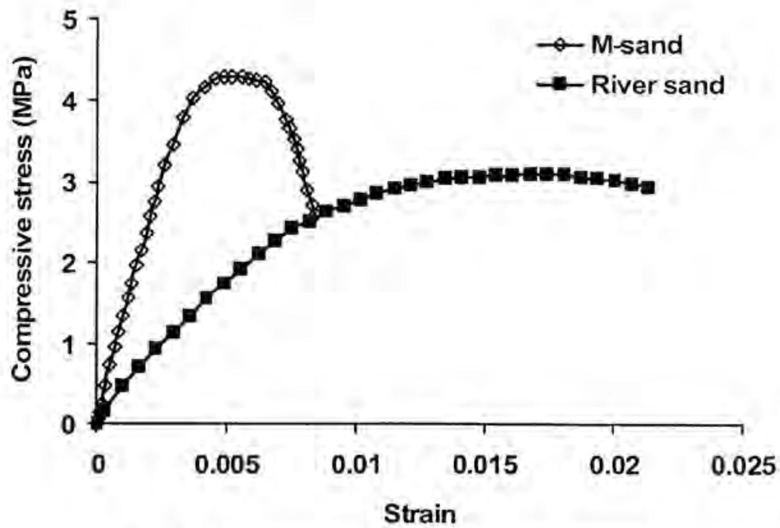


Fig. 7 – Strain-strain relationships for the masonry

5. Summary of results on mortars

The results of the tests on mortars and masonry using river sand and M-sand as fine aggregate can be summarised as follows.

1. Grading limits of M-sand falls within the grading Zone-11 sand, grading limits specified by IS 383 code.
2. Shapes of the M-sand particles resemble the shape of river sand particles.
3. Bulk density and specific gravity of M-sand are comparable to those of river sand.
4. Mortars with M-sand show better workability and require lower water-cement ratio to achieve a specific flow value when compared to mortars with river sand.
5. M-sand mortars show higher water retentivity values
6. Compressive strength of mortar with M-sand is higher than that of the mortar with river sand for mortar flow in the range of 85 - 100%.
7. Flexure bond strength of masonry using M-sand mortar is significantly higher when compared with the mortar using river sand.
8. M-sand mortar shows higher compressive strength and modulus for masonry when compared with the values for masonry using river sand.

6. Test results and discussion for concrete

Standard mix proportions for commonly used M20 and M30 grade concrete were selected following IS 456 code guidelines are given in Table 5. Various tests on fresh and hardened concrete were conducted following the guidelines of standard codes of practice mentioned in section 3.

Consistency of concrete: This was measured by conducting a slump test. Keeping the water-cement ratio at 0.50 and using super plasticizer (at 15 ml per kg of cement as specified by the manufacturer) the slump values were determined for both M20 and M30 mixes using river sand and M-sand as fine aggregate. Concrete with river sand gives higher slump value. IS 456 code specifies a minimum slump of 50 mm for medium workability. Both the concrete mixes meet this requirement irrespective of the type of sand.

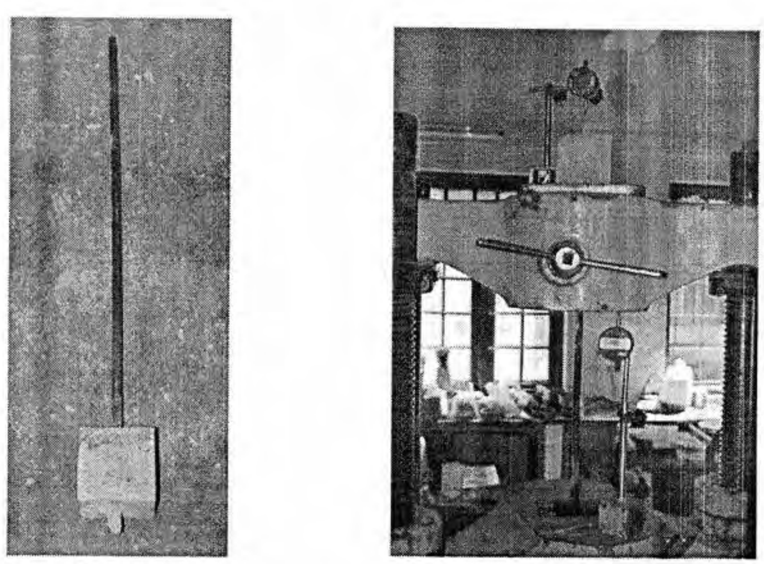
Compressive and flexure strength of concrete: Compressive strength was determined by testing the 28 days cured cube specimens (of size: 150 mm). The mean Compressive strength values of 5 cube specimens are reported in Table 5. Compressive strength of M20 and M30 grade concretes with M-sand as fme aggregate is 6 - 9% higher when compared with the results using river sand as fine aggregate."

Flexure strength of concrete was determined using prisms (size: 100 x 100 x 500 mm) following the IS 516 code guidelines. Three specimens were tested in each category and the mean values are reported in Table 5. The results show that use of M-sand as fine aggregate lead to 12 - 15% higher flexure strength when compared to the results of concrete with river sand.

Table 5 – Characteristics of concrete using M-sand and river sand
* C: cement, FA: Fine aggregate, CA: Coarse aggregate;
Standard deviation values in parenthesis

Mix proportion (by weight) (C:FA:CA)*	W/C ratio	River sand			M-Sand		
		Slump (mm)	Compressive strength (MPa)	Flexure strength (MPa)	Slump (mm)	Compressive strength (MPa)	Flexure strength (MPa)
1: 1.66: 3.33 (M30 grade)	0.50	80	42.20 (1.00)	3.90 (0.04)	55	44.78 (2.59)	4.54 (1.15)
1: 2: 4 (M20 grade)	0.50	110	37.68 (6.06)	3.29 (0.16)	76	41.03 (3.95)	3.86 (0.33)

Bond strength: The bond between rebar and the concrete was examined by conducting a pull out test. The pull out test was performed using 12 mm tor-steel bar for M20 concrete following the IS 2770 code guidelines. Fig. 8 shows the pull-out test specimens and the test set-up. The bond strength at failure (mean of three specimens) with river sand and M-sand as fine aggregate is 13.9 and 14.1 MPa respectively. The bond strength is marginally higher in case of M20 concrete with M-sand.



(a) Test specimen (b) Test set-up

Fig. 8 – Pull-out test

Stress-strain characteristics of concrete: Concrete cylindrical specimens of size 150 mm diameter and 300 mm height were cast using M-sand and river sand as fine aggregates. After 28 days of curing the cylinders were tested in a displacement controlled testing machine. Fig. 9 shows the test set-up with electrical resistance strain gauge in position and the typical failure of the concrete cylindrical specimen. Fig. 10 shows the stress strain curves (mean of three) for M20 concrete with M-sand and river sand as fine aggregate. Both the concretes show similar stress-strain behaviour. The secant modulus (at 30% of compressive strength) of the concrete (M20 grade) with M-sand and river sand is nearly equal at 24,000 MPa. The strain corresponding to peak stress is 0.0017 and 0.0021 for the concrete using river sand and M-sand respectively.

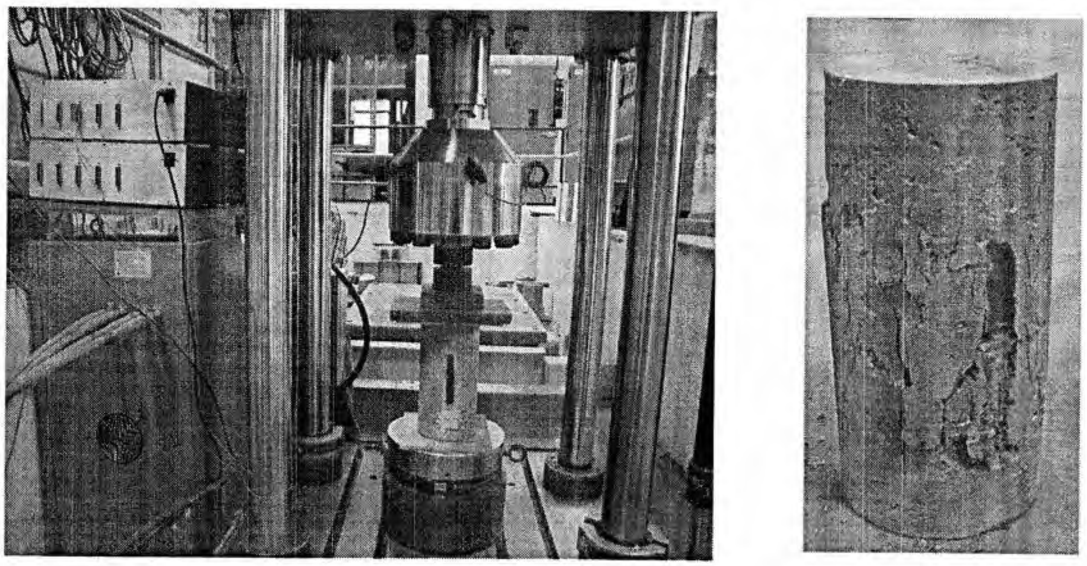


Fig. 9 – Test set-up for stress-strain measurements and the failure pattern of concrete cylinder

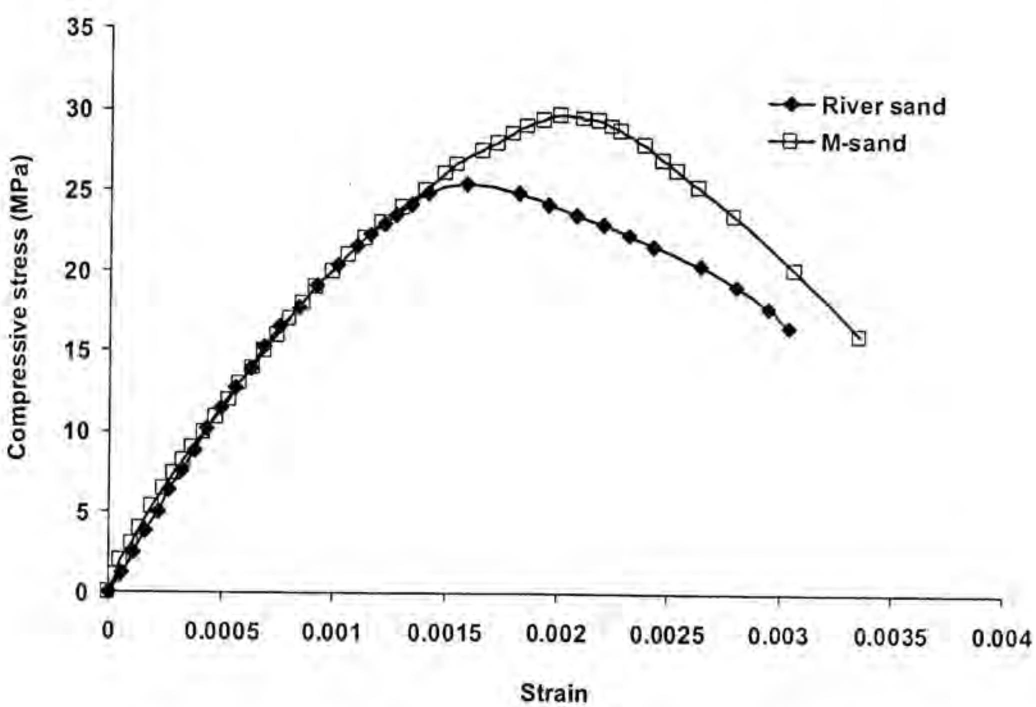


Fig. 10 – Stress-strain curve for concrete with M-sand

7. Summary of results on concrete

Two commonly used grades of concretes M20 and M30 were examined for their characteristics in fresh and hardened state. The results can be summarised as follows.

1. IS 456 code specifies a minimum slump of 50 mm for medium workability. M20 and M30 grade concrete mixes meet this requirement when M-sand is used as fine aggregate.
2. Compressive strength of concrete (M20 and M30) with sand is marginally higher (6 -9%) when compared to the concrete with river sand.
3. Flexure strength of M-sand concrete is 12 - 15% higher than that of river sand concrete.
4. Pull out bond test indicates marginally higher bond strength for M-sand concrete when compared with the bond strength of river sand concrete.
5. The stress-strain behaviour of M-sand and river sand concretes are similar. The secant modulus (at 30% of compressive strength) of the M20 grade concrete with M-sand and river sand is nearly equal at 24, 000 MPa

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4) IS: 383 - 1970 (2002), " Specification for coarse and fine aggregates from natural sources for concrete", Bureau of Indian Standards, New Delhi, India.
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11) Venkatarama Reddy, B. V. and Ajay Gupta, Characteristics of cement-soil mortars, Materials and Structures (RILEM), Vol. 38 (July 2005), No. 280, 639-650.

Summary and Recommendations

Characteristics of mortars, masonry and concrete were examined using M-sand as fine aggregate and the results were compared with those of river sand as fine aggregate. Two mortars (1:6 and 1: 4, cement : sand, by volume) and two grades of concrete (M20 and M30) were considered in these investigations. M-sand supplied by the Department of Mines and Geology was used. A natural river sand belonging to grading Zone - II sand classification (IS 383) was used for the purposes of comparison. The following points emerge from the experimental investigations using M-sand and river sand examined in the present investigation.

(1) M-sand is a well graded material and falls within the grading limits specified by the IS 383 code for grading Zone -II sand. Shape of the M-sand particles resemble with those of river sand particles. Flaky and elongated coarse particles are absent in the M-sand.

(2) Mortars with M-sand exhibit better workability and water retentivity characteristics.

(3) Compressive strength of mortars with M-sand is higher than that of the mortar strength with river sand for a given flow.

(4) Flexure bond strength of masonry using M-sand mortar is significantly higher than the mortar using river sand. This indicates better adherence of mortar to the masonry unit.

(5) Compressive strength and modulus for masonry using M-sand mortar is higher when compared with the values for masonry using river sand.

(6) Concrete with M-sand possess higher strength (compressive and flexure) when compared with river sand concrete.

(7) M-sand concrete possess better bond strength between rebar and concrete. M-sand concrete and river sand concrete have similar stress-strain behaviour and stress-strain characteristics.

IS 2116 and IS 383 codes on sand for mortars and masonry specify the use of crushed stone sand for concrete and masonry mortar. Some of the definitions and notes on crushed stone sand mentioned in these two IS codes are highlighted below.

1. IS - 2116, clause 2.3: Crushed stone sand and crushed gravel sand: A fine aggregate produced by crushing of stone or natural gravel.
2. IS - 383, clause 1.1: This standard covers requirements for aggregates, crushed or uncrushed, derived from natural resources, such as river beds, deposits, rocks, bed rocks and gravel.
3. IS - 383, clause 2.1.2: Crushed stone sand is a fine aggregate produced by crushing of hard stone
4. IS - 383, clause 2.1.3: Crushed gravel sand is a fine aggregate produced by crushing of natural gravel.
5. IS - 383, Table 4 (clause 4.3); This Table is about fine aggregates. Fine aggregates are grouped under four grading zones (Grading Zone I to IV). Table gives upper and lower bound limits for the grain sizes in each grading zone. Note 1 in this Table specifies the permissible limit enhancement for crushed stone sands. Note 1 reads as: "For crushed stone sands, the permissible limit on % passing 150-micron IS Sieve is increased to 20%. This does not affect the 5% allowance permitted in clause 4.3 applying to other sieve sizes".

The present investigation shows that the characteristics of mortars and concrete using M-sand as fine aggregate are superior when compared to the natural river sand as fine aggregate. The results pertain to the most commonly used grading zone - II sand. M-sand falling within the grading Zone II sand, grading limits specified by IS 383 code and manufactured from the hard rock is suitable as fine aggregate in concrete and masonry mortars. Also, IS-2116 and IS 383 codes permit the use of crushed stone fine aggregate in masonry mortars and concrete.

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Manufactured Sand - a Solution and an Alternative to River Sand in Concrete Manufacturing

A comparison study For M/S i-Blue Minerals, Karur
by INSTITUTE FOR CONSTRUCTION MATERIALS AND TECHNOLOGIES PVT LTD
(A Company Incubated by IIT Madras)

G. Sivakumar

MANUFACTURED SAND

Manufactured Sand is produced by feeding stones of varying sizes into Vertical Shaft Impact (VSI) Crusher. The VSI crusher by means of its unique design and action produces well shaped fine aggregate particles. The process of attrition also enables the removal of surface roughness of the fine aggregate particles to a good extent.

When the stones are processed through Vertical Shaft Impact (VSI) Crusher, not only fine aggregates, but the coarse aggregates, another end product, also acquire improved particle shape and reduced surface roughness.

VSI Crushers in quarry are sometimes used to convert entire coarse aggregates into fine aggregates.

With an inherent process of screening, Manufactured Sand plants ensure better grading of fine aggregates for better particle size distribution. Also some of the plants possess Air Filter System and/or washing facility through which the percentage of micro fines (passing 75 micron) is controlled below 3% by weight.

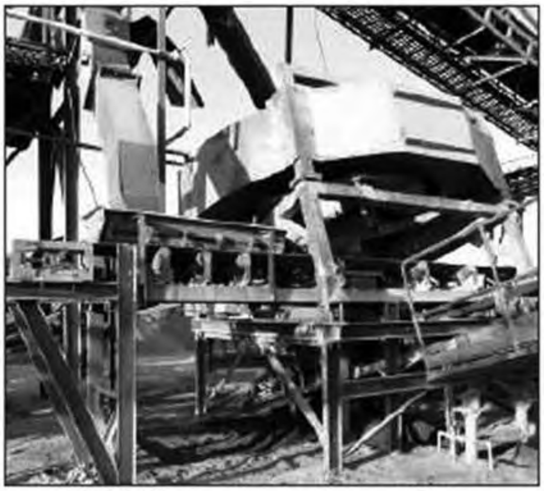
The washing facility provides another benefit of keeping the Manufactured Sand in wet or partially wet condition. This will help to reduce the absorption rate of Manufactured Sand during concrete manufacturing and in turn will contribute to the better workability and workability retention.

Test results in South India has shown that if the Manufactured Sand is produced by processing through VSI crusher and washing system, it exhibits much reduced water absorption character in comparison with Crusher Dust (CRF).

The systems aiding the process of Sand Manufacturing - From i-Blue Minerals.

VSI Crusher for Shaping

VSI with Air Filtering Technology (AFT)



ORTNER system to remove fines

Washing to remove fines - SANDTRAP

NATURAL SAND VS MANUFACTURED SAND

It is understandable that sand from river due to natural process of attrition tends to possess smoother surface texture and better shape. It also carries moisture that is trapped in between the particles. These characters make concrete's workability better.

However, silt and clay carried by river sand can be harmful to the concrete. Another issue associated with river sand is that of obtaining required grading with a Fineness Modulus of 2.4 to 3.1.

It has been verified and found, at various locations across South India, that it has become increasingly difficult to get river sand of consistent quality in terms of grading requirements and limited silt /clay content. It is because we do not have any control over the natural process.

In case of Manufactured Sand, the process of attrition through VSI and washing makes the Crushed-Stone- Sand particles good enough to be compared with shape and surface texture of natural sand.

With well designed screening system the required grading (Zone II) and Fineness Modulus (2.4 to 3.1) can also be achieved consistently in the case of Manufactured Sand.

When there is a need to control micro fines as in the case of the not-so-hard rocks, Manufactured Sand facilities can be equipped with Filter System and/or Washing System that can remove the micro fines.

It must be noted that properly processed Manufactured Sand can improve both compressive strength and flexural strength through better bond when compared to river sand.

Comparison between River Sand, Manufactured Sand, Crushed Rock Fines and Washed Crushed Rock Fines - Tests and Trial Mix Approach

Samples of River Sand from River Cauvery near Karur, Manufactured Sand (MS) from i-Blue Minerals, Karur, Crusher Dust or Crushed Rock Fines (CD/CRF) and Washed Crushed Rock Fines (WCRF) from another quarry in Karur were chosen for this study and analysis purposes.

Followings Tests and Trials were conducted for the comparison and evaluation:

Testing Plan

I. Sieve Analysis of RS, i-S (MS), CD/CRF and WCRF Samples
II. Percentage of microfines passing 75micron particles through wet sieving of RS, i-S (MS), CD/CRF and WCRF Samples

III. Water Absorption of RS, i-S (MS), CD/CRF and WCRF Samples
IV. Soundness Test for RS, i-S (MS) and CD/CRF Samples
V. Organic Impurities Test for RS and i-S (MS) samples
VI. Alkali-Silica-Reactivity Test (Accelerated Mortar Bar Test) for RS and i-S (MS) Samples
VII. Observation of particle shape of RS, i-S (MS) and CD/CRF Samples.

Trial Mix Plan

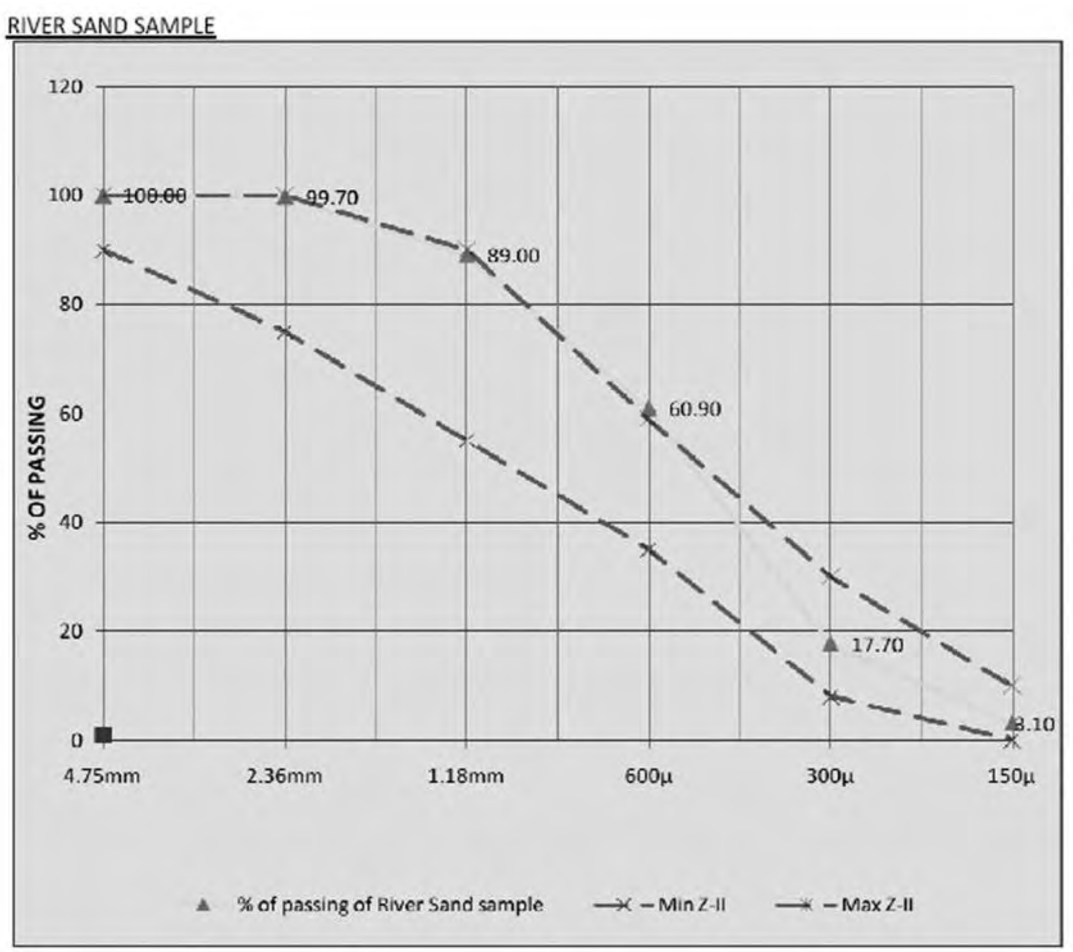
VIII. Comparison of workability & Cube Compressive Strength in mixes with 100% RS, i-S (MS), CD/CRF and WCRF

Nomenclature

RS – River sand
i-S (MS) – i-Sand, Manufactured Sand from i-Blue Minerals
CD/CRF – Crusher Dust/ Crushed Rock Fines
WCRF - Washed Crushed Rock Fines

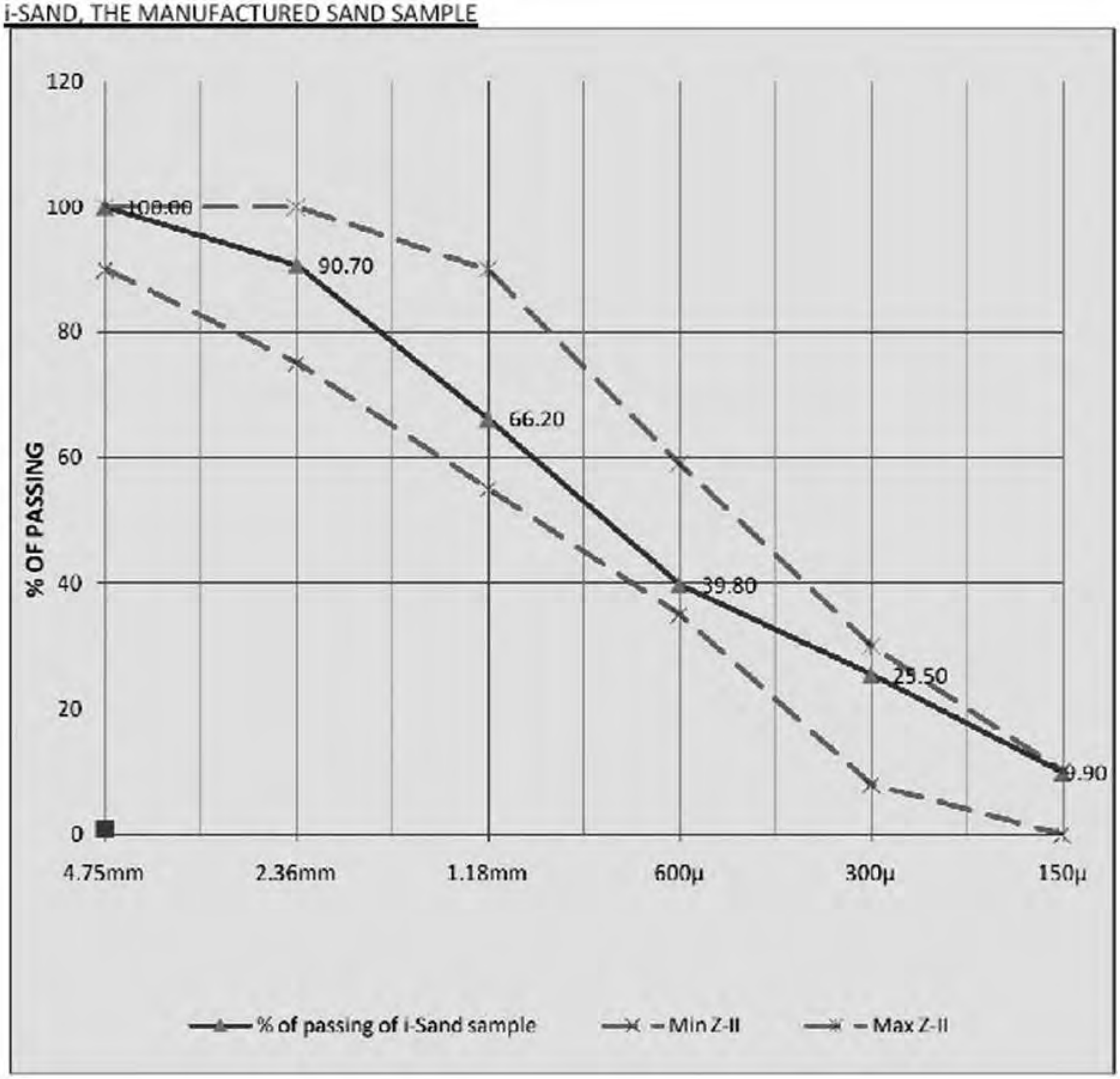
Testing, Results and Discussion

I. SIEVE ANALYSIS DATA



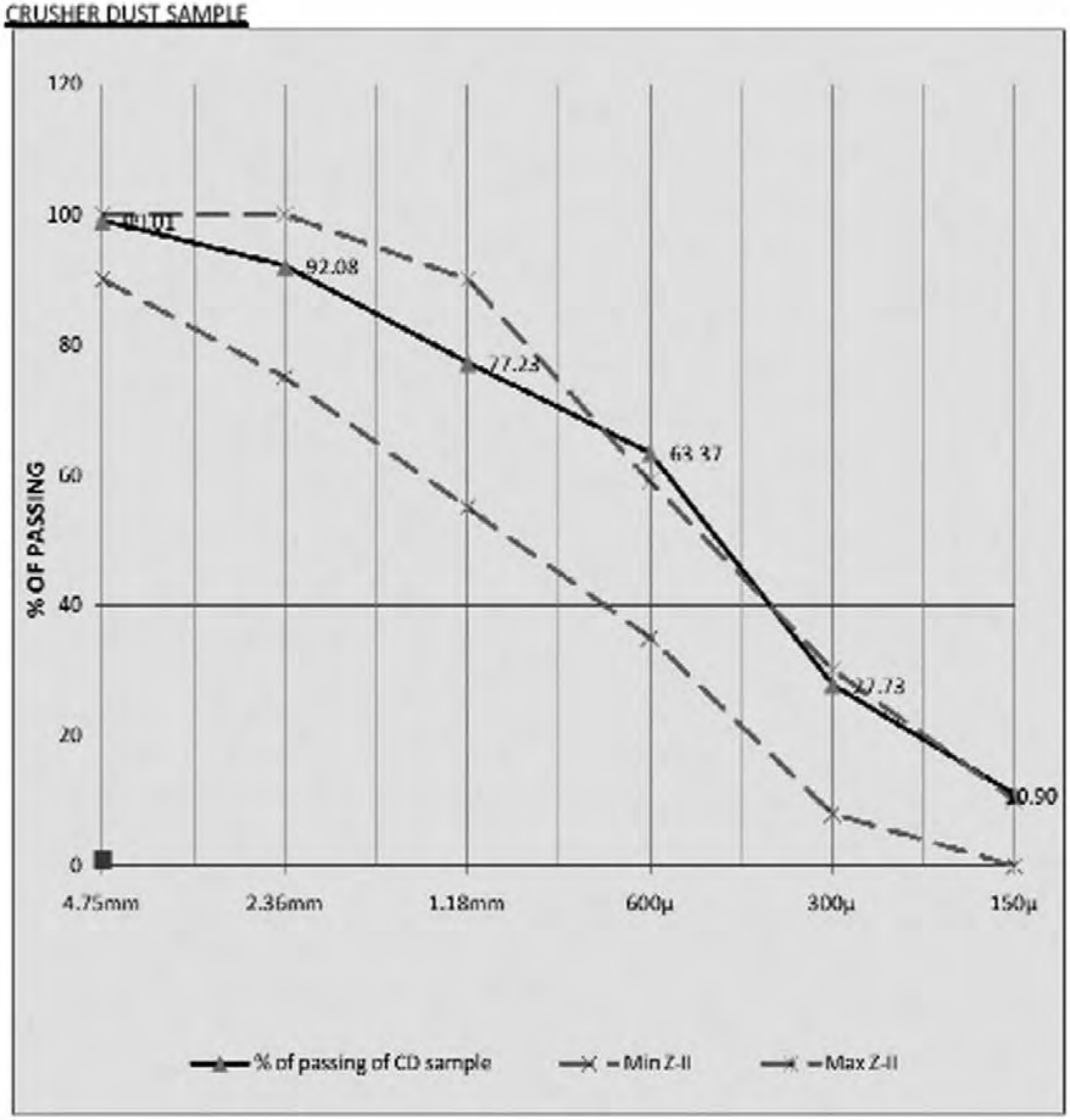
IS Sieve	% of passing of River Sand sample
4.75mm	100.00
2.36mm	99.70
1.18mm	89.00
600µ	60.90
300µ	17.70
150µ	3.10
Fineness Modulus	**2.30**

i-SAND, THE MANUFACTURED SAND SAMPLE

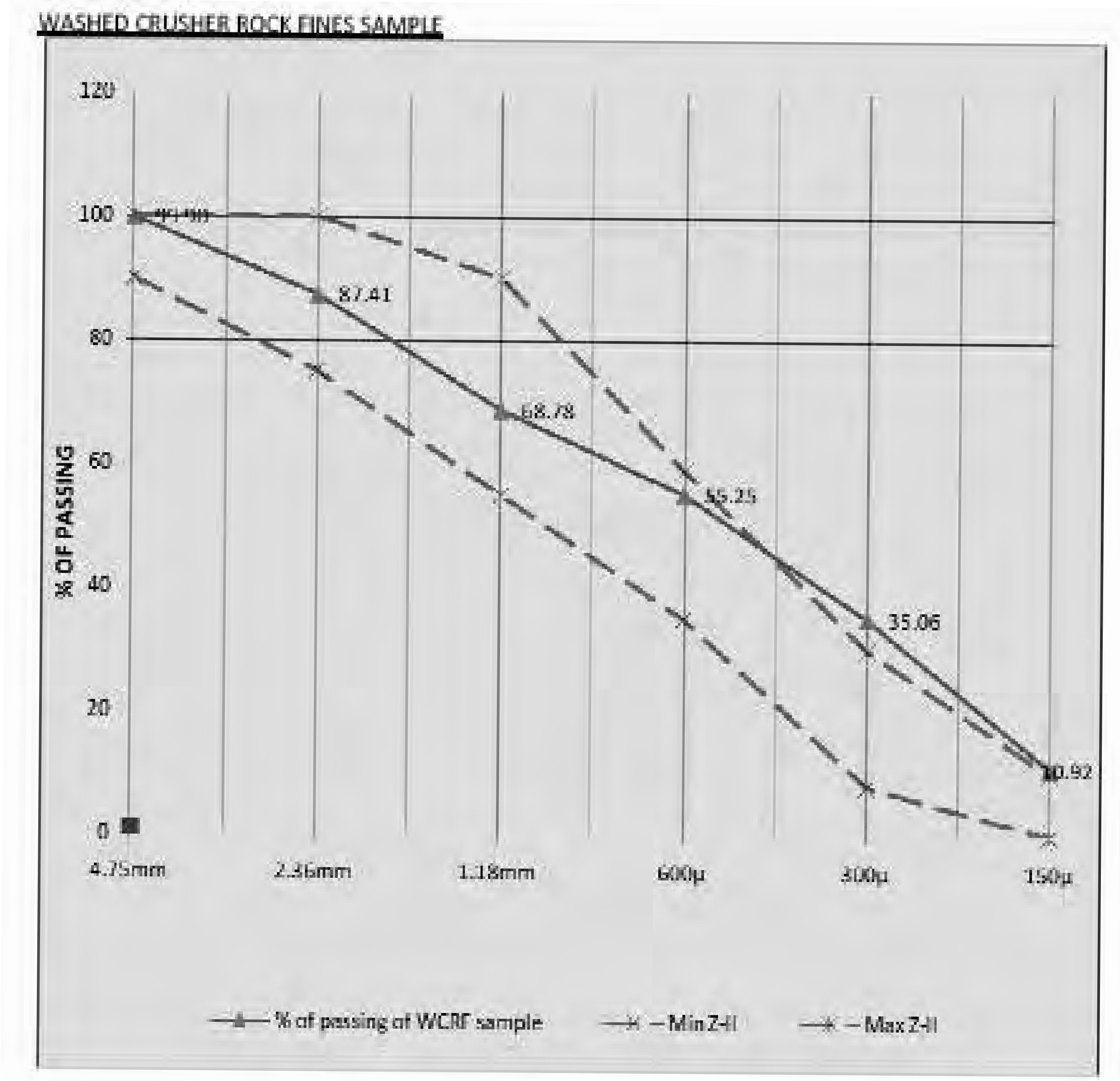


IS Sieve	% of passing of i-Sand sample
4.75mm	100.00
2.36mm	90.70
1.18mm	66.20
600µ	39.80
300µ	25.50
150µ	9.90
Fineness Modulus	**2.68**

CRUSHER DUST SAMPLE



IS Sieve	% of passing of CD sample
4.75mm	99.01
2.36mm	92.08
1.18mm	77.23
600μ	63.37
300μ	27.73
150μ	10.90
Fineness Modulus	**2.30**



IS Sieve	% of passing of WCRF sample
4.75mm	99.90
2.36mm	87.41
1.18mm	68.78
600µ	55.25
300µ	35.06
150µ	10.92
Fineness Modulus	**2.43**

II. WET SIEVING TEST TO FIND % OF MICROFINES

RIVER SAND SAMPLE

Test	Result	Remarks
Material finer than 75 Micron (%)	2.4	Finer than 75 Micron shall not exceed 3% for uncrushed aggregate as PER IS:383-1970 (Reaffirmed 2007)

i-SAND, THE MANUFACTURED SAND SAMPLE

Test	Result	Remarks
Material finer than 75 Micron (%)	2.00	Finer than 75 Micron shall not exceed 3% for uncrushed aggregate as PER IS:383-1970 (Reaffirmed 2007)

CRUSHER DUST/CRUSHED ROCK FINES SAMPLE

Test	Result	Remarks
Material finer than 75 Micron (%)	10.4	Finer than 75 Micron shall not exceed 3% for uncrushed aggregate as PER IS:383-1970 (Reaffirmed 2007)

WASHED CRUSHED ROCK FINES SAMPLE

Test	Result	Remarks
Material finer than 75 Micron (%)	2.00	Finer than 75 Micron shall not exceed 3% for uncrushed aggregate as PER IS:383-1970 (Reaffirmed 2007)

DISCUSSIONS

Grading – Particle Size Distribution through sieving

- Manufactured Sand (i-Sand) possesses better grading and meets Zone II requirement as it undergoes inherent sieving, filtering and washing processes.
- River Sand of Karur possesses good grading but with large size particles falling on finer limit.
- Both Crusher Dust (CD/CRF) and Washed CRF (WCRF) have failed to meet Zone II grading

requirements and possess excess fines content passing 600 micron and 300 micron respectively. Control of Microfines – Fines passing 75 micron sieve

- Manufactured Sand (i-Sand) has 2% microfines as the process of filtering and washing enables to control the percentage of micro fines.
- River Sand (RS) of Karur has 2.4 % microfines.
- Washed CRF (WCRF) has 2% microfines as the process of washing has controlled the microfines content.
- Crusher Dust or Crushed Rock Fines (CD/CRF) has a very high percentage of 10.4%, which could lead to increase in water demand, paste demand, loss of workability and loss of strength.

Note:

- Wet Sieving can identify correct % of microfines content, which would not be identified in dry sieving as microfines get stuck to the surface of the larger particles and would not pass through 75 micron sieve fully.
- River Sand with same percentage of Microfines by weight could occupy more volume in comparison with that of Crushed-Stone-Sand as Microfines in River Sand are foreign materials in the form of silt/clay content, whereas, Microfines in Crushed-Stone-Sand are the extracts from their parent rock or stones. So, for the same percentage of Microfines by weight, River Sand (RS) would normally have higher surface area.

III. WATER ABSORPTION TEST

River Sand from Karur	1.75%
i-Sand, Manufactured Sand, Karur	1.96%
Crusher Dust from Karur	3.86%
Washed Crushed Rock Fines, Karur	3.43%

DISCUSSIONS

- River Sand (RS) of Karur has the lowest absorption rate of 1.75% because of its polished surface texture resulting from the natural process of attrition.
- Crusher Dust or Crushed Rock Fines (CD/CRF) and Washed CRF (WCRF) have absorption rate of 3.86% and 3.43% respectively, which are much higher than the arbitrary limit of 2%. Presence of micro fines, rough surface texture and flaky shape of the particles are the reasons for such a high absorption rate. Presence of un-sound particles having higher porosity cannot be ruled out as well.
- Manufactured Sand (i-Sand) has absorption rate of 1.96% which is less than the recommended limit of 2% and the reason for lower absorption rate in this type of Crushed-Stone-Sand is, the mechanised process of attrition through VSI Crusher. The processing through VSI crusher has resulted in improving the shape of the particles and reducing the surface roughness to a good extent. Removal of microfines through filtering and washing also contributes to the reduced absorption rate.

Note:

- It must be noted that the process of washing of Crushed Dust (CD/CRF) has not reduced the absorption rate, significantly.

IV. SOUNDNESS TEST

RIVER SAND SAMPLE

Test	Test Conducted	Result	Remarks
Soundness Test	Sodium Sulphate (%)	5.79	The aggregate value shall not exceed 10% (5 cycles) by weight for aggregates when tested with Sodium sulphate. As per IS:383- 1970 (Reaffirmed 2007).
	Magnesium Sulphate (%)	7.64	The aggregate value shall not exceed 15% (5 cycles) by weight for aggregates when tested with Magnesium Sulphate. As per IS:383-1970 (Reaffirmed 2007).

i-SAND, THE MANUFACTURED SAND SAMPLE

Test	Test Conducted	Result	Remarks
Soundness Test	Sodium Sulphate (%)	1.6	The aggregate value shall not exceed 10% (5 cycles) by weight for aggregates when tested with Sodium sulphate. As per IS:383- 1970 (Reaffirmed 2007).
	Magnesium Sulphate (%)	2.00	The aggregate value shall not exceed 15% (5 cycles) by weight for aggregates when tested with Magnesium Sulphate. As per IS:383-1970 (Reaffirmed 2007).

CRUSHER DUST/CRUSHED ROCK FINES SAMPLE

Test	Test Conducted	Result	Remarks
Soundness Test	Sodium Sulphate (%)	7.74	The aggregate value shall not exceed 10% (5 cycles) by weight for aggregates when tested with Sodium sulphate. As per IS:383- 1970 (Reaffirmed 2007).
	Magnesium Sulphate (%)	7.96	The aggregate value shall not exceed 15% (5 cycles) by weight for aggregates when tested with Magnesium Sulphate. As per IS:383-1970 (Reaffirmed 2007).

DISCUSSIONS

- The tests show that River Sand (RS) of Karur and Manufactured Sand (i-Sand) and Crushed Rock Fines possess required soundness. However, Manufactured Sand (i-Sand) is found to be better than River Sand and CRF in this aspect. The possible reason is, the mechanised process of attrition, screening and washing could have contributed to good, solid and rigid particles.

Note:

- Soundness Test is conducted to verify the ability of aggregates to with stand long term effect of Alternate Wetting & Drying and/or Freeze & Thaw.

V. ORGANIC IMPURITIES TEST

RIVER SAND SAMPLE	i-SAND, MANUFACTURED SAND SAMPLE
	

Remarks:

- Organic impurities test shows that both River Sand and i-Sand are clear of any organic impurities.

DISCUSSIONS

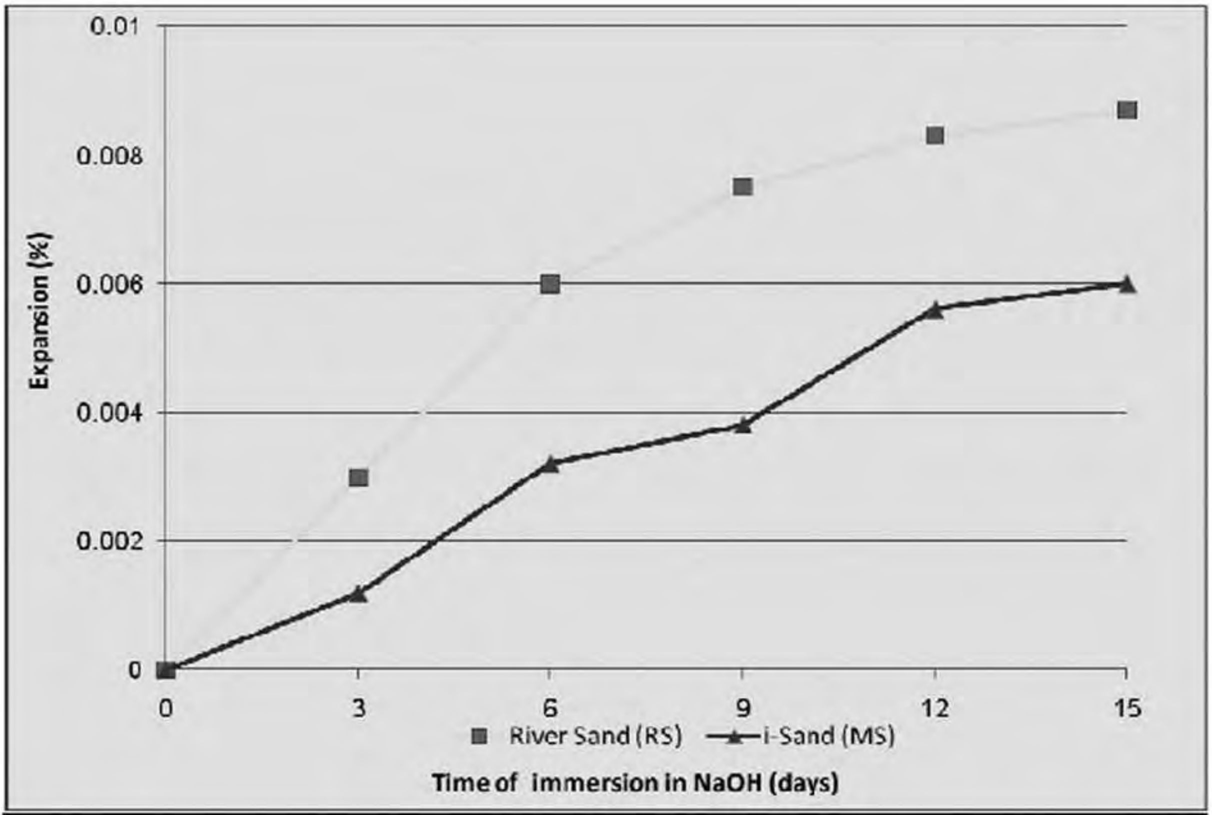
Organic Impurities – Color Test

- Both River Sand (RS) of Karur and Manufactured Sand (i-Sand) are found to be free of organic impurities.

Note:

- Organic impurities are mostly found in River Sand due to matters like decayed vegetations, algae, etc carried by river. These impurities may cause workability loss and delayed setting in concrete.

VI. ALKALI SILICA REACTIVITY TEST



Remarks:

- ASR test is conducted as per ASTM C1260, Accelerated Mortar Bar test.
- The samples can be considered non-reactive or innocuous when the expansion on 14th day is less than 0.1%.

DISCUSSIONS

- Both River Sand (RS) of Karur and Manufactured Sand (i-Sand) showed much lower expansion compared to the limit of 0.1% that qualifies them as innocuous material.

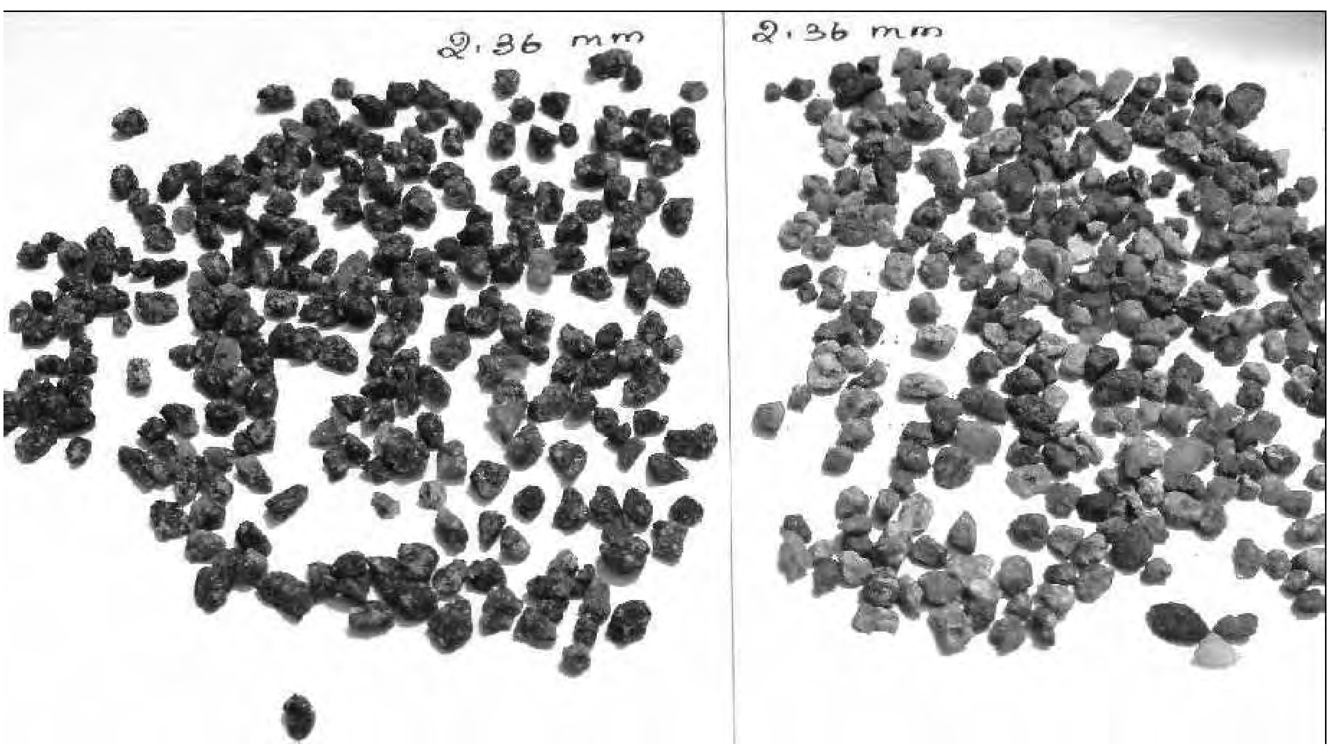
Note:

- If aggregates contain reactive silica, it can react with alkali in cement during the process of hydration and can result in formation of Alkali-Silica-Gel. This gel imbibes water from concrete and expands. The expansion causes disruption in concrete and makes it to disintegrate or crack.
- Accelerated Mortar Bar Test as per ASTM C-1260, is one of the test methods to verify this potential reaction between Alkali in cement and possible reactive Silica content in aggregates. If mortar bar expansion is less than 0.1%, then the aggregate is considered innocuous or non-reactive.

VII. PARTICLE SHAPE VERIFICATION

Good Shape of i-sand visualised in 2.36mm sieve (retained)

Flakiness of CRF visualised in 2.36mm sieve (retained)



Shape of i-sand, the Manufactured sand equivalent to River Sand retained by 2.36mm sieve

DISCUSSIONS

- The shape of River Sand (RS) tends to be good. However, Manufactured Sand (i-Sand) particles match the shape of River Sand particles very closely.
- The shape of Crushed Rock Fines remains flaky and elongated.

Note:

- The shape verification test was done by sieving the respective fine aggregates particles through 4.75mm sieve and retained at 2.36mm sieve. The particles between the size of 4.36mm and 2.36mm are verified visually for their shape. This method is considered suitable, especially on field, as it is quick and easy. The same method can be used to verify the shape of the particles between 2.38mm and 1.18mm, too.

COMPARISON TABLE OF TEST RESULTS

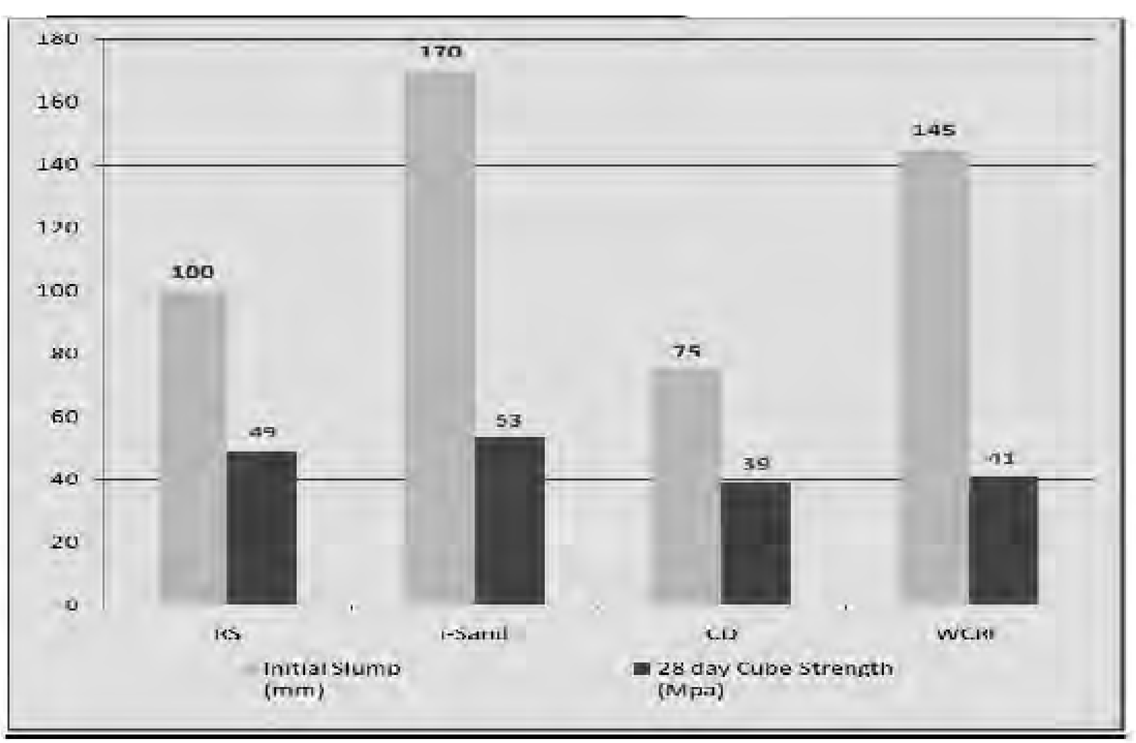
Sl No	Properties and Tests	River Sand (RS)	i-Sand (MS)	Crusher	Dust (CD/CRF)	Washed CRF (WCRF)	Limits/ Requirements
1	Grading Zone II – Sieve Analysis	FM 2.3	Finer side of Zone II	FM 2.68 Proper Zone II Grading	FM 2.3 Excess fines passing 600micron Finer than Zone II		Zone II
	FM 2.43 Excess fines passing 300micron Finer than Zone II						
2	Material finer than 75 Micron (% by weight) – Wet Sieving	2.4%	2%	10.4%	2%	Limit is 3%	
3	Water Absorption-Absorption Test	1.75%	1.96%	3.86%	3.43%	Excess to 2% is not recommended	
4	Soundness Test Sodium Sulphate	5.79 %	1.6%	7.74		Limit is 10%	
	Magnesium Sulphate	7.64 %	2.00%	7.96		Limit is 15%	
5	Organic Impurities Test	OK	OK			Colour2	
6	Alkali Silica Reactivity-Accelerated Mortar Bar Expansion Test	0.0087	0.006			Limit is 0.1%	
7	Particle Shape-Physical Verification	Good	Good	Flaky	Flaky	Good	

Trial Mix, Results and Discussion

TRIAL MIXES FOR COMPARISON ON STRENGTH AND WORKABILITY DISCUSSIONS

Trial Mix Reference number		LT046 (100% RS)	LT047 (100% MS)	LT048 (100% CRF)	LT050 (100% WCRF)
Material	Source	Weight (kg/ cum)	Weight (kg/ cum)	Weight (kg/ cum)	Weight (kg/ cum)
Cement	Zuari 53Gr Primo	325	325	325	325
20mm down	i-blue minerals	1020	1020	1020	1020
River sand	i-blue minerals	840			
M.Sand (i-Sand)	i-blue minerals	850			
Crusher Dust (CD/CRF)	Karur			840	
Washed CRF Karur 840					
Water	Internal	170	165	175	170
Admixture	SP123	1.78	1.78	1.78	1.78
		2357	2362	2362	2357
Workablity					
Slump @ 5min	100 mm	170 mm	75 mm	145 mm	
Cube Compressive strength					
28 day		49	54	38	41
28 day		49	51	39	40
28 day Average	49	53	39	41	

Graphical Comparison on workability and Strength



DISCUSSIONS

Workability

- The mix with Manufactured Sand (i-Sand) as 100% fine aggregates gives initial workability of 170mm, which is much higher than that of the mixes with 100% River Sand (RS) and Crusher Dust (CD/CRF).
- Higher Fineness Modulus, Particles grading, Shape, texture and control of microfines have contributed to better workability of Manufactured Sand (i-sand). The good physical properties of M.Sand has enabled in reduction of free water as well.
- The standard mix with Washed CRF (WCRF) as 100% fine aggregates gives initial workability of 140mm. Higher Fineness Modulus and removal of microfines would have contributed to the workability that is better than Crusher Duct (CD/CRF) and River Sand.
- Though River Sand Particles have better shape and texture, lower Fineness Modulus and Silt Content would have contributed to the reduced workability of just 100mm, which is much lower than that of the standard mix with 100% Manufactured Sand (i-Sand).
- The mix having 100% CD/CRF has poor workability even with increased water content. Obviously, physical properties and microfines had affected the workability.

Compressive Strength

- The Standard Mix with 100% Manufacture Sand (i-Sand) has exhibited much higher compressive strength of 53 MPa.
- The Standard Mix with 100% River Sand (RS) has exhibited a compressive strength of 49 MPa, 7.5% lower than that of Manufacture Sand (i-Sand).
- The standard mixes with Crusher Dust (CD/CRF) and Washed CRF (WCRF) as 100% fine aggregates have attained the much lower compressive strength results of 39 MPa and 41 MPa respectively.
- The improved properties of Manufactured Sand (i-Sand) by the entire process of manufacturing could have resulted in reduced surface area and better particle packing. This could have contributed to the better binding effect with the available cement paste and thereby improved the compressive strength.
- In the case of other two Crushed-Stone-Sand namely Crusher Dust (CD/CRF) and Washed CRF (WCRF), though there is possibility of better bonding due to surface roughness, the other factors namely increased surface area, poor gradation and presence of microfines would have made binder content in-sufficient to match the strength level of the standard mix with 100% of Manufactured Sand (i-Sand).
- Though there is a slender increase in w/c ratio for the mixes having CD/CRD and WCRF by 0.03 and 0.02 respectively in comparison with mix having M.Sand, that would not have contributed to such a big difference in strength.

Note:

- Laboratory cube compressive strength results tend to be higher in comparison with field/plant results due to accuracy and better control exercised during laboratory trials.

CONCLUDING REMARKS

Usage of good quality river sand with consistency to manufacture concrete has become increasinglydifficult in India. Depletion of resources has not only made good quality river sand a scarce material but also directs Technocrats decisively, to look for better alternative in order to prevent ecological damage.

The technology to manufacture sand through VSI crushers has evolved through series of research and development works abroad. Though this technology found acceptance in developed countries like European Union, Australia, New Zealand and Japan quite a sometime ago, other Asian countries like China, India, Singapore, Malaysia and Vietnam have started adopting this Technology for the past 5 to 6 years.

Hundreds of thousands of cubic metre of concrete from normal grade to high grade is being produced worldwide, with good consistency with Manufactured Sand as an important ingredient. It is found out through various studies, including this one that Concrete Manufacturing, with optimal Cement and Admixture content and consistency in quality, is becoming cost effective when these processed or Manufactured Coarse and Fine Aggregates are used. The cost paid to the Technology in comparison with savings obtained is lesser. Most importantly savings of cement by enhancing the properties of aggregates through a manufacturing process is a big contributing factor to ecology.

The Technology of Manufactured Sand and Coarse Aggregates could well be the solution for the Indian Concrete Industry.

ACKNOWLEDGEMENT

We would like to express our whole hearted and sincere gratitude to Prof.Ravindra Gettu of IIT Madras for the support provided for this study. His guidance amidst his busy schedule had contributed immensely in fulfilling the objective of this study.

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Manufactured Sand as Fine Aggregate

Sanjay Bahadur and N.V. Nayak

1 SHORTAGE OF NATURAL SAND

There is growing shortage of natural sand in many cities. The severity varies from market to market, and in some cases this may not appear to be a priority topic. Eventually, pressure from environmentalists and sand conservationists worldwide will continue to encourage both legislators and construction engineers to look for viable alternatives to natural sand. Cubical sand manufactured from crushed rock is the most desirable fine material for concrete production. It is generally accepted that particle shape depends on the rock type, breakage energy and the type of crusher used. The rocks are crushed using crushers to manufacture coarse aggregates and the fines which are produced are usually flaky and has been used in filling, asphalt etc. Manufactured sand is defined as purpose made crushed fine aggregate produced from a suitable source material.

In many places within the country, the problem of non-availability of natural sand is increasing with each passing day. It is further aggravated by the seasonality, inconsistency and volatility that are associated with extraction and supply of natural sand. In the market, the need for good quality manufactured sand is evident and the market has started to move towards the same. The government has banned sand dredging in many parts of the country.

2 OPTIMUM SHAPE

The optimum shape of manufactured sand is spherical, next best being cubical. Similarly, an even gradation of the total coarse aggregate fraction is desirable so that the smaller particles can fit between the larger particles, thereby minimizing the voids. Well-shaped aggregates also minimize the incidence and degree of segregation. It has been proven that more than 20kg of cement can be saved for every cubic meter of concrete that is made by replacing a poorly shaped aggregate with a cubical aggregate. In addition, both compressive strength and flexural strength are improved by using cubical aggregates, which also increases workability and reduces bleeding and shrinkage. The impact of the physical characteristics of the sand used in concrete mix is even greater than that of the coarse aggregate fractions, both in the concrete's plastic and hardened states.

3 VOID CONTENT

The principles of total internal friction and void content apply equally to the fine fraction, but because of the vastly smaller particle size and therefore the greatly increased surface-area-to-volume ratio, any detrimental or undesirable shape or texture properties will be greatly amplified. Similarly, manufactured sand presents an opportunity to control the mineral content in the particles. Natural sand often contains undesirable minerals and clays, and the effect of these materials on both the fresh and the hardened states of concrete can be extremely harmful. For example, the effect of clay particles in fresh concrete is not obvious, as the particles absorb disproportionate volumes of water and hence swell to many times their original size. This swelling occupies a volume in the cement paste in its fresh state. When it hardens, however, the clay particles contract and leave minute voids, which in turn increase the shrinkage and permeability and hence reduces the concrete's chemical resistance and compressive strength. Other undesirable materials, ranging from basic chlorides to harmful chemicals, can exist in this fine material fraction. The use of manufactured sand, however, reduces the risk of impurities.

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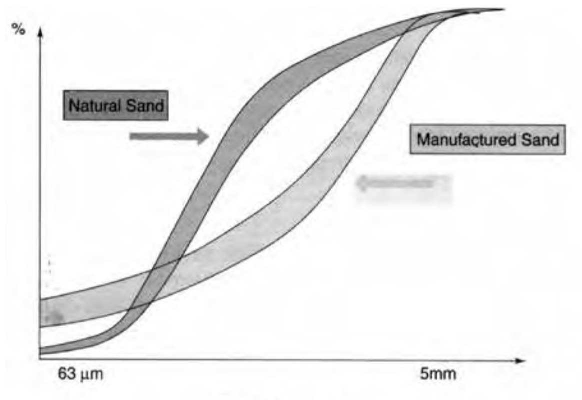
Comparison Between Manufactured Sand and Natural Sand

Manufactured sand	Natural sand
A fine aggregate produced by crushing rock grovel or slag	It is the result of natural weathering and abrasion of rock
• Can often be floky & elongated displaying sharper, angular edges a rough surface texture	• Mostly alluvial or weathered rock, but can of marine origin also be
• Higher micro-fines content	• Natural sands are rounded and smooth



Manufactured Sand Performance Drivers

	Parameters	Has impact on
ROCKS INTRINSIC PARAMETERS	Petrography of rocks	Manufacturing process (wear & tear)
	• Structural Geology of deposit	
	• Faults, weathering	
	Rock mechanical parameters	
	• Hardness, crushability	
	• Abrasiveness	
PRODUCTS AND APPLICATIONS	Particle size distribution	Concrete applications
	Particle shape	• Rheology
	Micro-fines	• Strength
	• Content (<75m)	• Concrete surface aspects
	• Type (clay, other impurities)	• Durability Road applications
		• Ability to compact |
		• Adhesion (anti-stripping)

From a user's perspective, manufactured sand performance can be improved by improving

- Grading curve
- Shape
- Micro-fines content

Gradually concrete production with 100 percent manufactured sand as fine aggregate is slowly increasing. In such cases, specially manufactured naphthalene based super plasticizers are generally used. Occasionally the use of viscosity modifying admixture is necessary to enhance the consistency and workability of concrete mixtures containing 100 percent manufactured sand fine aggregate.

4. A MANUFACTURING PROCESS

many markets in India, the current practice is to use single staged Jaw crushers for aggregates.

The fine aggregate produced through this process is extremely irregular in shape and other surface properties. Also, the overall process is of very small scale and primitive, with no scalping stage in the process flow. The lack of scalping in process leads feeding of all unclean materials from quarry into the main crushing flow, and thereby results in high level of inconsistency in grading, especially in the finer fines. This also leads to lack of control on the properties of fine particles, as the content of clay and impurities can be sometimes very high and generally inconsistent as per feed. Also, many players cash in on the sand crisis by front-ending the process with low quality VSI-s, without investing in a total revamp of process. This leads to the end product being labelled as Manufactured sand, but in actuality the product would end up having a slightly better shape, but high level of inconsistency and contamination, leading to decreased durability and higher mix cost to achieve strength due to increased cement content. There are a few players who are now investing in proper process control, and with larger companies including Multinationals entering the foray, the market seems to be set towards moving to a better structure in days to come.

5 OPTIMAL PROCESS

The optimal process for manufactured sand could be a 3-stage crushing and screening process, which in turn can be of the following configuration

Primary Jaw → Secondary Cone → Tertiary Vertical Shaft Impactor

OR

Primary Jaw → Secondary Cone → Tertiary Cone

Both processes have their respective advantages and disadvantages. While using a VSI in the tertiary stage improves the shape of the particles, it in turn produces higher micro-fines. This can be arrested by using a cone in the tertiary stage, but care should be taken in selection of the right cone crusher for the purpose.

Using a washing process (wet classification) or an air classifier can reduce the content of micro-fines in the sand, but leads to disposal hazards of the waste product which can be in conflict of inclusive and sustainable construction practices. More work needs to be done in the area of how the extracted micro-fines can be recycled & effectively used in other applications, reducing the otherwise highly hazardous environmental impact associated with indiscriminate disposal to a minimum.

6 TESTS FOR MANUFACTURED SAND

From the producer and users' perspective, the main areas of control while producing or using manufactured sand shall be

- Particle size distribution and content of micro-fines
- Properties of aggregates associated with assessment of fines (noxiousness)
- Properties of aggregates associated with surface characteristics (shape)

IS Sive Size (mm)	Cumulative % Passing	
	Lower Limit	Upper Limit
10	100	100
4.75	90	100
2.36	75	100
1.18	55	90
600m	35	59
300m	8	30
150m	0	20
75-	0	15
Pan		

(*) Though these are the limits as per IS 383, it is desirable to restrict these values respectively to 15 and 10.

For determining the other two characteristics, noted herein below, there is a lack of sufficiency of Indian standard tests and we I to turn to international standards for the same.

Particle size distribution (PSD) and content of micro-fines

the PSD and content of micro-fines, the grading (sieve) analysis should be used as a deterministic test. The following table can be used in accordance with IS:383-1970 for the purpose.

Properties of aggregates associated with assessment of fines (noxiousness)

The methylene blue value test (MBV) can be used as a deterministic test for the assessment of the characteristics of fines. The relevant international code is the British Standard BS EN 933-9:1999 or the equivalent European Standard EN 933-9:1998 and is titled as "Tests for geometrical properties of aggregates Part 9: Assessment of fines - Methylene blue test".

Principally, the standard specifies a method for the determination of the methylene blue value of the 0-2 mm fraction in fine aggregates or all-in aggregates (MB). Increments of a solution of methylene blue are added successively to a suspension of the test portion in water. The adsorption of dye solution by the test portion is checked after each addition of solution by, carrying out a stain test on filter paper to detect the presence of free dye. When the presence of free dye is confirmed the methylene blue value (MB or MBV) is calculated and expressed as grams of dye adsorbed per kilogram of the size fraction tested.

Properties of aggregates associated with surface characteristics (shape)

The flow coefficient of aggregates test can be used as a deterministic test for assessment of surface characteristics (shape) of aggregates. The relevant international code is the NF EN 933-6, titled as "Tests for geometrical properties of aggregates Part 6: Assessment of surface characteristics — Flow coefficient of aggregates".

This European Standard specifies methods for the determination of the flow coefficient of coarse and fine aggregates. It applies to coarse aggregate of sizes between 4 mm and 20 mm and to fine aggregate.

The flow coefficient of an aggregate is the time, expressed in seconds, for a specified volume of aggregate to flow through a given opening, under specified conditions using a standard apparatus.

Procedure - Select a funnel, using the 12mm opening for 0-2mm fine aggregates or 16mm opening for 0-4mm fine aggregates. Fit the cylindrical body to the selected funnel and place it on its stand, its opening closed off. Place the test portion in the flow unit, restricting the height of fall to avoid compacting the material.

Open the orifice and at the same time start the stopwatch, record the time to 0.1 s for all the material to flow through the funnel. Repeat five times, using the same test portion, recording the time for each single determination.

The flow coefficient expressed in seconds of the fine aggregate being tested, is the average of the five single determinations rounded off to the nearest second.

The details of apparatus used for determination of flow coefficient of both coarse and fine aggregates are furnished in Figs. 1, 2 and 3 as given in Euro code EN 933-6:2001 (E)

Note: The Figs. 1, 2 and 3 should be reproduced from the code.

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Concerns on the Use of Filtered Sand and Sea Sand for Construction

Aswath M U

INTRODUCTION

The use of filtered sand and sea sand, witnessed many problems for civil engineers. Many monitoring authorities have raised concerns about the quality of these types of sand. In India there are ample examples of failures due to the use of filtered sand. The Times of India reports the Concerns expressed by the Lokayukta on the use of 'filtered sand' at construction sites in May 2008 and also a report was sent to the state government on 'filtered sand' being used for construction of buildings. The report was dictated by a concern on the need to ensure that quality sand extracted in an environment-friendly manner is used for construction of buildings. [1]

We also have reports on problems of using sea sand in many parts of the world. One such report says, "Shenzhen construction on hold after alert over cheap sand in concrete-Work on highest tower suspended after report of developers using cheap sea sand in concrete. More projects are likely to be affected as the Shenzhen government ordered a citywide inspection into the practice, which they said was common throughout the Pearl River Delta. Untreated sea sand contains high levels of salt and chloride that could corrode steel reinforcements, causing buildings to collapse" [2]

FILTERED SAND

The use of 'filtered sand' for construction of buildings is increasing due to the restrictions on river sand. There is a strong need to ensure the quality of such sand before using it. It is said that the methods adopted for filtering the sand are very crude and mostly it is by manual washing in pits and small ponds. Proper filtering/washing methods are not adopted hence the quality of filtered sand is questionable. There are some limits for deleterious materials in the fine aggregates as per IS: 383-1970. **Especially the clay and silt content should not be more than 1% by**

weight and material finer than 75µ should not be more than 3% by weight. The total deleterious materials for uncrushed fine aggregates should be less than 5% by weight. It is very important to control the quality of the aggregate to be used in concrete making. Most importantly, the effect of the clay/silt content of sand on the compressive strength of concrete must be controlled. It is also observed by the researchers that the higher the percentage of clay/silt content in sand, the higher the percentage increment of cement needed for the same compressive strength of the concrete at 28 days. Studies have shown that for 10% clay/silt content in sand there will be up to 50% increment of cement.[3]

The engineers at sites report that the clay and silt content is more in filtered sands. The major concern is, even today many of our buildings are built without engineers'

supervision and in many construction sites there are no facilities to check the quality of sand and especially clay and silt content. In such a scenario one must be very careful before using the filtered sands. In addition to the poor engineering properties, filtered sand is also facing the concerns of environmentalists and these should be addressed before using the filtered sand as an alternative to river sand.

SEA SAND: Sea sand contains higher % of chloride ions which increases corrosion in steel. It also has very high content of shale and is finer than river sand. In concrete generally coarse sand is most suitable. Due to shortage of sand near coastal areas, properly washed and screened sea sand can be used for making concrete if ample water is available to treat/ wash the sea sand to lower chloride content or if fly ash in desired proportion can be added to balance chloride ions. Fly ash mixed sea sand should also be chemically tested for final chloride ions in the mix to ensure desired durability of concrete w.r.t. corrosion in steel.

"Treating the sea sand is very costly and it requires a large area to soak it in [fresh] water," says Chan Chi-Ming, who is head of the department of construction at the Institute of Vocational Education. He said the soaking process was intended to remove all traces of the salt. [3]

A professional at a Hong Kong construction company says no developer here would risk using sea sand. "If it is not treated well, the concrete will peel off the building after 10 years or so."[3]

The Sri Lanka Land Reclamation and Development Corporation in association with the civil engineering department of the University of Moratuwa and the National Building Research Organisation have carried out some studies and recommend sea sand as a sustainable alternative to river sand. The studies show that the salinity level in the sea sand extracted from the off shore sea, is very much less than the salinity level in the sand in the beach. The sand has been pumped from a distance of about 10 km from the sea coast there. The sand stockpiles of sand there have been exposed to the monsoonal rains for a period of nearly 8 years and due to this they claim the salinity has been washed away.

Countries such as United Kingdom, Netherlands, India, Seychelles Islands, Singapore, Japan and Korea are using sea sand for construction. The study to use sea sand for cement concrete is a big problem of civil engineering field. In many countries sea sand has been used for making cement concrete since long time and the technology depends on the research achievement and specific conditions of each country. ***Before recommending the sea sand as an alternative, the sand samples must be studied in the laboratories to determine: the components and fineness modules of sea sand grains; Unit volume of sand; content of mica in the sand; content of dust, mud, clay; Volume of foam; Sea salt in the sand; and the content of shell in sea sand.*** Generally the strength of cement concrete using sea sand is less than traditional cement concrete up to 10%. [4]

New technologies in the marine industry have made offshore dredging operations economically more attractive. Especially in countries with large coastal resources and limited land-based sand reserves, marine aggregates constitute up to 25% of the total production of natural aggregates. [5] In Japan and Great Britain, which produce two-thirds of the world's marine aggregates, offshore sand and gravel mining have already become a 200 million USD industry.[6]

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Durability Studies on Pond Ash Concrete

Kalgal, M. R. and Pranesh R.N

INTRODUCTION:

Ash generated as a by product in the thermal power plants is accumulating on an enormous scale posing danger to the environment. Of this ash, fly ash is primarily being used in the manufacture of blended cements or as partial replacement of cement in making concrete. A large amount of information is available on use of fly ash as a replacement to cement1,2,5,7,8. Unused fly ash and bottom ash are mixed in slurry form and deposited in ponds and is known as Pond Ash. Very little work is reported in use of pond ash as partial replacement to sand6,9,10. Extensive Studies have been undertaken by the authors to explore the possibility of utilising this Pond Ash in making of concrete. Characterisation of pond ash samples was carried out and results indicated that Pond ash could be tried as fine aggregate in concrete. Authors then carried out investigations on the probable mix proportioning and durability of concrete with pond ash as a fine aggregate. This paper summarizes the findings of the research carried out by the authors on durability.

RESEARCH SIGNIFICANCE

The deposition of Pond Ash in lagoons or ash ponds adjacent to thermal plants is assuming alarming proportions, creating disposing problems and environmental hazard. There is a dire necessity to find avenues for the extensive use of Pond Ash. One such avenue is to explore the possibility of using Pond Ash as fine aggregate, either partly or fully replacing natural river sand which is becoming scarce. When concrete is made with pond ash, it is required to study if strength and durability are affected. Since it was found that pond ash could replace sand as fine aggregate partially or fully without compromising on strength3,4, an elaborate study on durability aspects was conducted.

EXPERIMENTAL PROGRAMME:

Pond ash samples were procured from Raichur Thermal Power Plant (R T P S), Karnataka, India. Durability studies included study on effect of sulphate, Chloride, Acid, corrosion and permeability. These studies have been carried out on concrete containing pond ash as a partial and total replacement to sand.

Materials:

a. Cement

Ordinary Portland Cement (43 grade) conforming to IS: 8112-1989 was used throughout the investigation.

b. Sand and coarse aggregate

Good quality river sand without any impurities has been used in this investigation. Physical properties of sand obtained were Bulk Density-1467 Kg/m^3 in loose state and 1687 Kg/m^3 in compacted state, Specific Gravity – 2.6 and Fineness modulus- 2.6. Locally available crushed granite passing through 10mm & retaining on 4.75mm IS sieve was used as coarse aggregate. Physical properties of coarse aggregate obtained were Bulk Density- 1470 Kg/m^3, Specific Gravity –2.67 and Fineness modulus-6.

c. Pond Ash

A total of 16 pond ash samples have been collected from different locations in the ash pond of RTPS. Physical and chemical charecterisation have been done on few representative samples[3]. Physical properties of pond ash obtained were Bulk Density-824 Kg/m^3 in loose state and 990 Kg/m^3 in compacted state, Specific Gravity – 2.02 to 2.47 and Fineness modulus- 1.2. SEM studies have been carried out on four typical samples and XRD analysis has been carried out on two typical samples. As the grain distribution and other physical properties for all the samples were identical, pond ash samples obtained from all locations was thoroughly mixed and used in the investigation. Figure 1 gives the grain size distribution of the sample. Table 1 gives chemical analysis results of the same.

Mix Proportioning:

1. For mix proportioning based on maximum workability two preliminary mix proportions (A and B) were chosen Tables 2 and 3 give the mix proportion for maximum compaction factor for these mixes.

2. Two mix proportions were chosen based on best particle packing approach, using Modified Andreasson Theory(one with 0% pond ash and the other with 40% sand replacement level). Table 4 gives the mix proportion for C and D. In these mixes 2% of Sulphonated Naphthalene polymer based super plasticizer was used to obtain a workability of 8 to 9 Vee Bee seconds.

3. One more study was undertaken wherein the total fine aggregate was pond ash only. Table 5 gives the mix proportion for these mixes with a coarse aggregate to pond ash ratio of 68:32 (E and F). In these mixes, super plasticizer percentage was increased to 4% to obtain a medium workability of 8 to 9 Vee Bee seconds.

It was observed from water absorption tests on pond ash that percentage absorption of water is 10%. This correction has been applied in the mixes C, D, E and F above.

Durability Studies:

100mm cube specimens, 100 × 200mm cylindrical specimens, 75 × 75 × 450mm prisms and 100mm diameter 50mm thick cylindrical specimens have been cast and cured for 28 days to study effect of

1. Sulphate, chloride and acid with respect to weight loss and strength- conducted on all mixes (A, B, C, D, E and F).

2. Sodium chloride on reinforcement in concrete with respect to corrosion potential- conducted on mixes C, D, E and F.

3. Chloride penetration (Rapid Chloride Penetration Test-RCPT)- conducted on mixes C,D,E and F

Studies on Mix A and B:

Effect of sulphate (5%), Chloride (5%) and acid (10% of 2N HCl) environments on concrete were studied by immersing 28 days cured 100 mm cubes in these solutions and recording weight loss and compressive strength at 28, 90 and 270 days of exposure. Tables 6 to 11 variation of strength with age for Mix A and Mix B specimens when immersed in $MgSO_4$, NaCl and HCl solutions for all replacement levels. Since the variation in weight was negligible, it is not reported explicitly.

Studies on mix C and D

Specimens of mix C and D were subjected to sulphate, chloride, acid, corrosion and permeability tests as mentioned above.

Exposure to sulphate, chloride and Acid solutions:

28 days cured 100mm cubes were immersed in solution containing 5% Mg SO_4, 5% Na Cl and 10% of 2N HCl and at regular intervals weight loss and compressive strength were determined for 28, 56 and 90 days of exposure. Tables 12 and 13 give the values of compressive strength for specimens of mix C and D. Since here also the weight loss/gain was negligible, the values are not given.

Determination of Corrosion Potential:

This test was conducted as per ASTM specifications using half cell potentiometer. Test was carried out on 75mm × 75mm × 450mm prism in which one 8mm diameter bar is placed such that the bar is projecting on either side by minimum 25mm for connecting the leads of the testing apparatus. These specimens were immersed in 5% NaCl solution after 28 days of curing. Corrosion potential was measured in milli Volts at 28, 56 and 90 days. Table 14 gives the values of increase in corrosion potential for specimens of Mix C and D. This was obtained as the difference between corrosion potential at a given time and its value immediately after 28 days curing.

Rapid Chloride Penetration Test (RCPT):

This test is a measure of permeability of concrete and was carried out as per ASTM specifications. Cylindrical specimens of diameter 100mm and height 50mm were cast and cured for 28 days for conducting RCPT. Table 14 gives the value of chloride ion penetration in coulombs for specimens of mix C and D at 28, 56 and 90 days.

Studies on mix E and F

Specimens of mix E and F were subjected to sulphate, chloride, acid, corrosion and permeability tests as mentioned. Tables 15 and 16 give the values of strength and percentage decrease in weight for specimens of mixes E and F. Table 17 gives the values of corrosion potential and RCPT values for the same.

Discussions

As mentioned earlier, the variation in weight was almost negligible. As can be seen from results in tables 6 to 11, with respect to strength, generally strength increased with age inspite of specimens being immersed in $MgSO_4$, NaCl and HCl. This strength gain with age was higher in pond ash concrete than normal concrete. For specimens of Type A mix immersed in HCl strength gain was significantly less than that in other specimens. With respect to type B mix strength was comparable with other specimens. For specimens of Type C and Type D mix immersed in above mentioned solutions same trend has been observed up to 90 days and investigations are being continued up to 180 days. Referring to table 14 for corrosion potential and RCPT values for specimens of Type C and Type D mix up to 90 days, it can be seen that corrosion potential values are very close to threshold value of -350mV (for no corrosion to occur) up to 28 days and thereafter values were much below the threshold value. With respect to RCPT values, we can observe that Type C concrete can be classified as one with medium permeability and Type D concrete can be classified as one with low permeability. For specimens of type E and type F immersed in $MgSO_4$, NaCl and HCl solutions, marginal weight gain was observed up to 360 days. Marginal strength gain was observed in specimens immersed in NaCl solution and marginal strength loss in other two solutions up to 360 days (tables 15 and 16). Referring to table 17 for corrosion potential and RCPT values, it was found that the corrosion potential was slightly higher than threshold value of -350mV (for no corrosion to occur). With respect to RCPT, we can observe that this concrete can be classified as one with very low permeability.

Conclusions:

Based on durability studies conducted it can be broadly concluded that:

1. Behaviour of pond ash concrete is comparable with normal concrete in terms of strength and durability.

2. Concrete with the sand replaced completely with pond ash likely to perform comparatively better than concrete with partial replacement of sand .

3. Strength loss concrete immered in HCl is generally higher than concretes immersed in other solutions.

4. With respect to corrosion potential and RCPT values, pond ash concrete appears to perform better than normal concrete.

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Table 1: Chemical analysis results of pond ash samples

LOI (%)	3.46
Total Silica (%)	67.40
Alumina (Al_2O_3) (%)	19.44
Iron Oxide (Fe_2O_3) (%)	8.5
CaO (%)	2.7
MgO (%)	0.45
Sulphuric anhydride(SO_3) (%)	0.30
Insoluble Residue (%)	90.58
Soluble Salts (%)	0.17

Table 2: Mix proportion for Type A

Mix	Cement	Pond Ash	Fine Aggregate	Coarse Aggregate	Water
0% Pond Ash	330	0	825	1140	185
20% Pond Ash	330	94	377	1494	185
30% Pond Ash	330	141	330	1494	185
40% Pond Ash	330	189	283	1494	185

Table 3: Mix proportion for Type B

Mix	Cement	Pond Ash	Fine Aggregate	Coarse Aggregate	Water
0% Pond Ash	430	0	764	972	172
20% Pond Ash	430	83	333	1319	172
30% Pond Ash	430	125	292	1319	172
40% Pond Ash	430	167	250	1319	172

Table 4: Mix proportion for Types C and D

Mix	Cement Kg/m^3	Fine Aggregate Kg/m^3	Pond Ash Kg/m^3	Coarse Aggregate Kg/m^3	Water Cement ratio	Water lts/m^3
Control Mix (C)	330	820	0	1044	0.56	185
40% Pond Ash (D)	330	492	268	1044	0.56	185

Table 5: Mix Proportions for Types E and F

Grade of Concrete	CA:FA (%)	Cement (kg/m^3)	Pond Ash (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (l/m^3)	Super Plasticizer (l/m^3)
E	M-III	330	540.47	1148.5	208.24	7.7
F	M-III	343.75	537.32	1141.82	208	8.02

Table 6: Strength variation for Type A specimens in $MgSO_4$

% Pond	Compressive strength in MPa		
Ash	28 days	90 days	270 days
0	42.66	41.33	35
20	42	42.33	51.33
30	44.33	47	47.66
40	41.33	45.33	50.33

Table 7: Strength variation for Type B specimens in $MgSO_4$

% Pond	Compressive strength in MPa		
Ash	28 days	90 days	270 days
0	50	57.33	52.33
20	47.33	57.66	70.33
30	46.33	58.66	64
40	41.67	56	71

Table 8: Strength variation for Type A specimens in NaCl

% Pond	Compressive strength in MPa		
Ash	28 days	90 days	270 days
0	40.66	41.66	52
20	43.66	38	59
30	43.66	48.66	58
40	42.33	44.33	59.66

Table 9: Strength and variation for Type B specimens in NaCl

% Pond	Compressive strength in MPa		
Ash	28 days	90 days	270 days
0	47.66	47.33	56.66
20	44.33	56	76.66
30	47.33	46.33	67.66
40	43.67	45	62.33

Table 10: Strength variation for Type A specimens in HCl

% Pond	Compressive strength in MPa		
Ash	28 days	90 days	270 days
0	37.66	38.66	34.67
20	40.33	41	45.66
30	44	46.66	40.33
40	41.66	43.67	40.66

Table 11: Strength variation for Type B specimens in HCl

% Pond	Compressive strength in MPa		
Ash	28 days	90 days	270 days
0	53.66	50.33	47.66
20	45	49	55.33
30	49	49	47.33
40	51.33	55.66	50

Table 12 . Strength variation for Type C specimens

Immersion Solution	Mg SO_4			NaCl			HCl		
Age (days)	28	56	90	28	56	90	28	56	90
Strength in N/mm^2	52.00	54.67	55.7	52.67	57.50	49.3	32.67	43.00	37.7

Table 13. Strength variation for Type D specimens

Immersion Solution	Mg SO_4			NaCl			HCl		
Age (days)	28	56	90	28	56	90	28	56	90
Strength in N/mm^2	52.3	52.7	49.0	51.3	57.3	52.3	33	37	33.0

Table 14: RCPT values and Increase in corrosion potential for Types C and D

Mix	Mix C			Mix D		
Age(Days)	28	56	90	28	56	90
Increase in corrosion potential(mV)	-362	-313.6	-330.1	-340	-276	-294.0
RCPT values as charge						
passed in coulumbs	3072	1998	1997	2052	1522	929

Table 15. Strength variation for Type E specimens

Immersion Solution	Mg SO_4				NaCl				HCl			
Age (days)	28	90	180	360	28	90	180	360	28	90	180	360
Strength (N/mm^2)	31.3	35.7	40.3	36.0	33.0	36.3	37.0	40.7	31.0	27.7	32.0	28.3

Table 16. Strength variation for Type F specimens

Immersion Solution	Mg SO_4				NaCl				HCl			
Age (days)	28	90	180	360	28	90	180	360	28	90	180	360
Strength (N/mm^2)	40.00	43.00	37.66	33.00	43.00	35.33	34.67	39.33	37.00	35.00	32.00	37.00

Table 17: Increase in corrosion potential and RCPT values for Types E and F

Mix	Mix E			Mix F		
Age(Days)	28	56	90	28	56	90
Increase in corrosion potential(mV)	-467	-441	-438.2	-408	-395	-348.5
RCPT values as charge passed in coulumbs	1340	694	660	1409	705	623

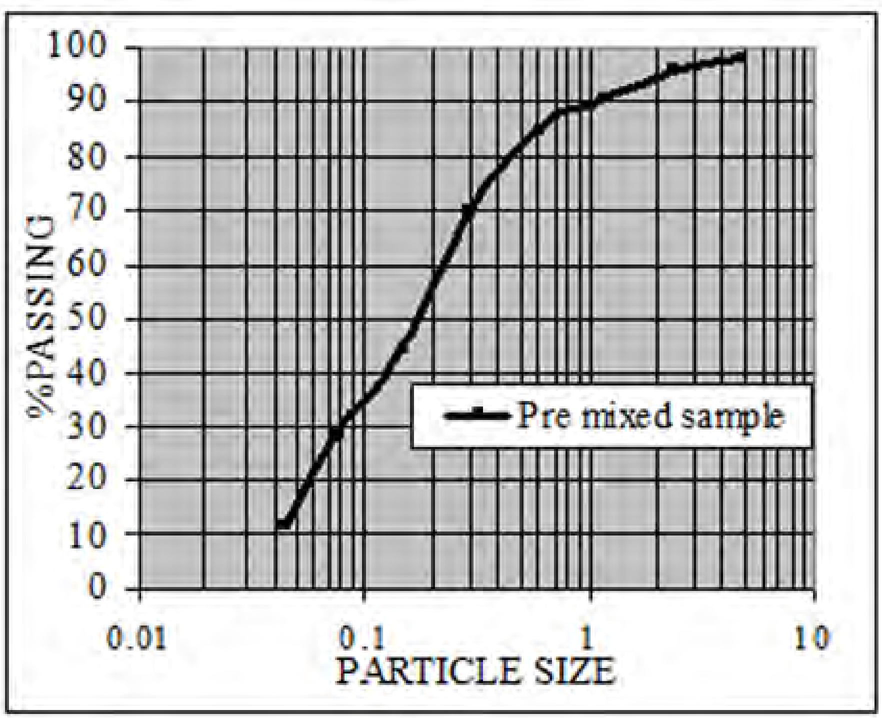

Fig1 Grain Size distribution of Pre mixed Pond Ash sample

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Granulated Steel Slag - An Alternative To River Sand

**S M R Prasad, D Satish Kumar
R Sah and Ganapathi Prasad**

1. Introduction

River Sand is the most preferred fine aggregate for mortar and concrete. River sand is a product of natural weathering of rocks over a period of millions of years and is mined from river beds. Sand mining has disastrous environmental consequences. The excessive mining of river bed is creating an ecological imbalance. This has lead to have restrictions imposed by Ministry of Environment on sand mining. Driven by the acute need for sand, stone dust or manufactured sand prepared from the crushing and screening of coarse aggregates is being used as sand in the recent past. However manufactured sand is also a natural material and has quarrying and quality issues. To reduce the burden on the environment, alternative materials to be used as fine aggregates are being extensively investigated all over the world [1-8]. Looking to the quantum of requirements, quality and properties there has been a global consensus on a material - Granulated Slags. Granulated slag has been proven as a suitable material for replacing natural sand / crushed fine aggregates [1,2,6]. In developed countries, the use of granulated slag as fine aggregate to replace natural sand is well established and is in regular practice. In the present paper granulated steel slag has been experimented for usage in mortar.

Slags are the main by-products generated during iron and steel production in the steel industry. Over the past decades, the steel production has increased and, consequently, the higher volumes of by-products and residues generated which have driven to the reuse of these materials in an increasingly efficient way. In recent years new technologies have been developed to improve the recovery rates of slags. Increase of slags recovery and use in different fields of applications like cement making, construction and fertilizers help in preserving natural resources. In addition to the environmental protection, these practices produced economic benefits, by providing sustainable solutions that can allow the steel industry to achieve its ambitious target of "zero-waste" in coming years. Slags are generated at two different stages of steel production, Iron making and Steel making known as BF slag and Steel Slag respectively. The slagging agents are fluxes, such as limestone, dolomite and quartzite added into BF or steelmaking furnaces in order to remove impurities from ore, scrap and other ferrous charges during smelting. The slag formation is the result of a complex series of physical and chemical reactions between the non-metallic charge (limestone, dolomite, fluxes), the energy sources (coal, coke, oxygen, etc.) and refractory materials. Because of the high temperatures (about 1500°C) during their generation, slags do not contain any organic substances. Due to the fact that slags are lighter than the liquid metal, they float and get easily removed. The slags protect the metal bath from atmosphere and maintain temperature through a kind of lid formation. These slags are in liquid state and solidified in air after dumping in the pit or granulated by impinging water stream.

Generally, BF slags are granulated and used in cement making due to its high cementious properties, and steel slags are mostly dumped due to un-favourable physio-chemical conditions. The increasing dump of steel slags not only occupies plenty of land, but also wastes resources and can potentially have an impact on the environment due to water pollution. Since BF slag contains little Fe and can be used directly. BF slag has found a wide application, such as cement production, road construction, civil engineering work, fertilizer production, landfill daily cover, soil reclamation, and so on. However, steel slag due to its high metallic content is usually subjected to metal recovery prior to its application outside the iron and steel making process.

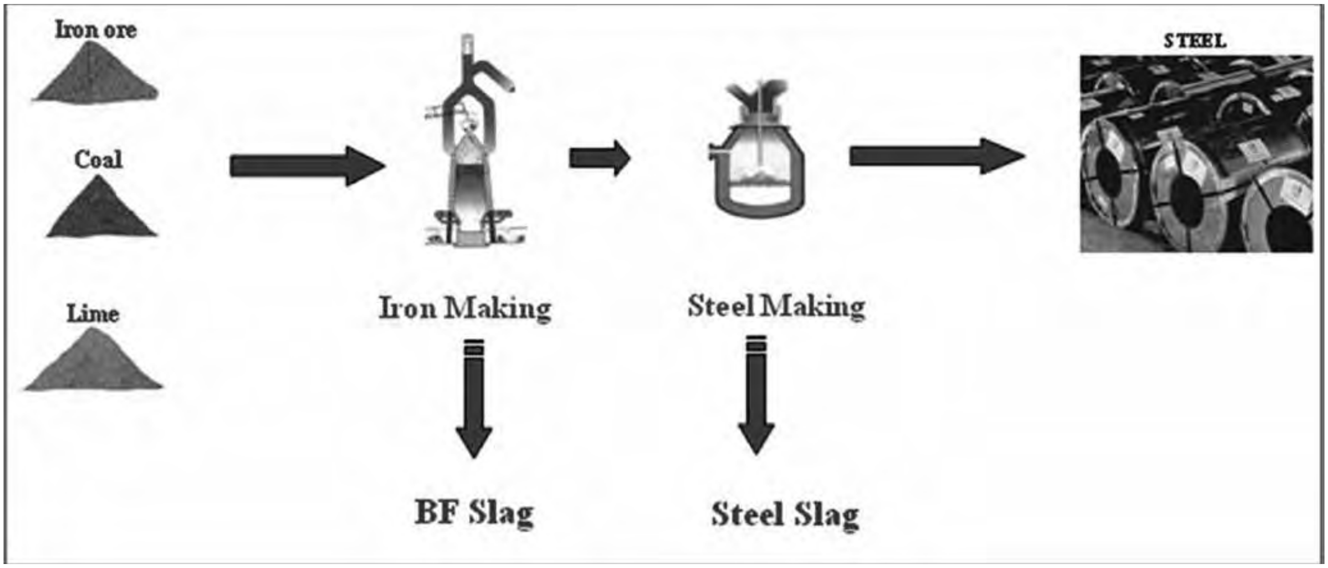

Fig 1: Slag generation in steel plant

2. Granulated LD Slag (GLDS)

Steel slag also called as LD slag is generated from BOF process (using the Linz-Donawitz converter or LD converter) involving pig iron refining process, which converts molten pig iron and steel scraps into high quality steel. Most slags from steel plant derive from this process, with an average of 150-200 kg of slag generated per tonne of steel produced. X-ray diffraction studies have shown that the major phases present in LD slag are dicalcium ferrite, calcium alluminate and wüstite, but it also contains some reactive mineral phases, such as 2CaO.SiO2, 3CaO.SiO2 and free CaO and MgO. The major reason for not having water granulation of BOF slag is to avoid Fe getting trapped in the matrix whereas, with air-cooling, the Fe can be removed via magnetic separation. Another reason was that the high iron increases the risks of explosions when the BOF slag is water granulated. Unlike blast-furnace slag, steel slag shows volumetric instability mainly due to the presence of free magnesium oxide (MgO) and lime (CaO). In the presence of water, these compounds hydrate expansively. The swelling nature of steel slag is detrimental to almost all civil engineering applications. Hence, the main purpose of treating slag is to decrease the volume instability caused by the expansive components of steel slag by changing its chemical and/or mineralogical properties. In the literature, there are examples of special steel slag treatment techniques that are used in some steel plants to minimize the undesirable volumetric instability of slag. These techniques include using additives, steam treatment, and ageing. The terms "ageing" or "weathering" of steel slag, refer to the open-air stock piling of steel slag to provide adequate exposure to moisture. However it is a slow process and not feasible for large integrated steel units.

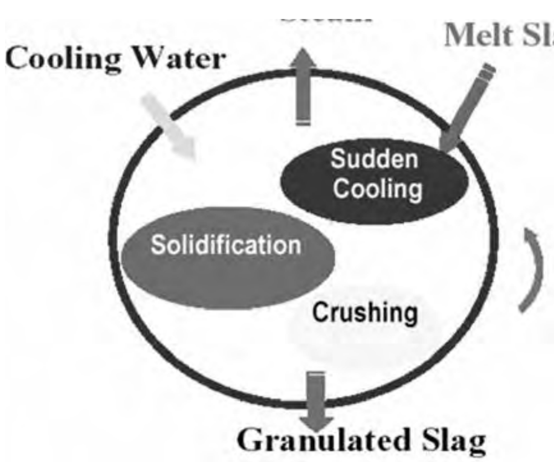

Fig 2: Slag Granulation Mechanism

Fig 3: Slag Granulation Plant

At JSW steel, LD slag is subjected to granulation through an innovative quenching technology (Figure 2), adopted, first of its kind in India. The technology separates the metal and slag in a closed system as shown in Figure 3 and also washes out free lime and MgO. Due to sudden quenching, of the molten slag, differential contraction of metal and slag occurs and results in good separation of metal and slag. Adequate granulation takes place and leads to good stability of the final slag. Process can be called as accelerated ageing process which reduces the unwanted free lime content. Removal of free lime and MgO also confirms its volumetric stability. Granulated slag particles are hard and have plain surface texture. Particles are very strong, anti-weathering and anti-wearing with reduced free lime, reduced FeO and negligible metallic iron.

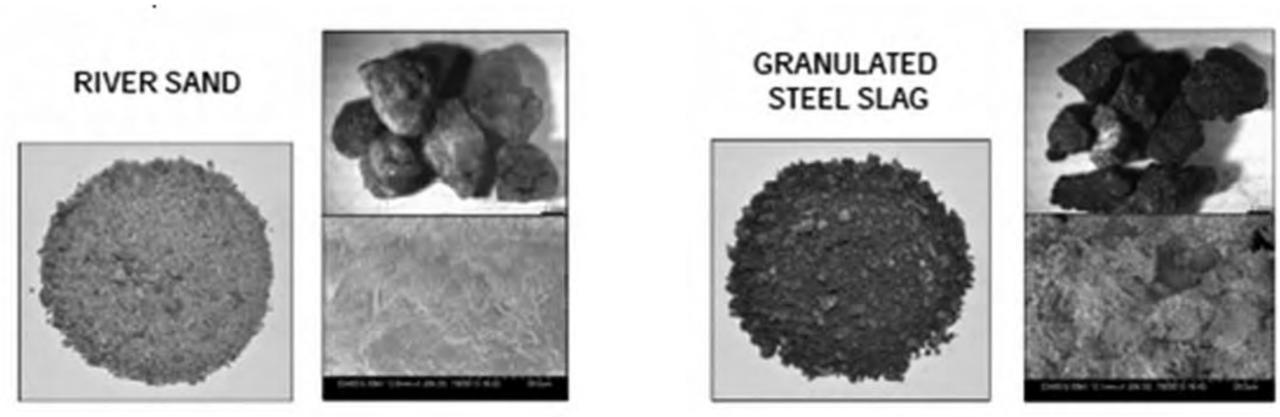

Fig 4: Comparison of river sand with granulated steel slag

Shape of the granulated slag sand is similar to river sand. Microscopically river sand and manufactured slag sand are also similar as shown in Figure 4. The granulated slag is screened to different size fractions based on application and requirement and is shown in the Figure 5. This wide distribution of size is required in aggregates used in construction. Due to its similarity to river sand this is seen as a potential material for replacing river sand in construction. However, to meet the requirement of specified fine aggregates, detailed characterization and laboratory tests are required. The present paper highlights the granulated steel slag characteristics and its usage in mortar.

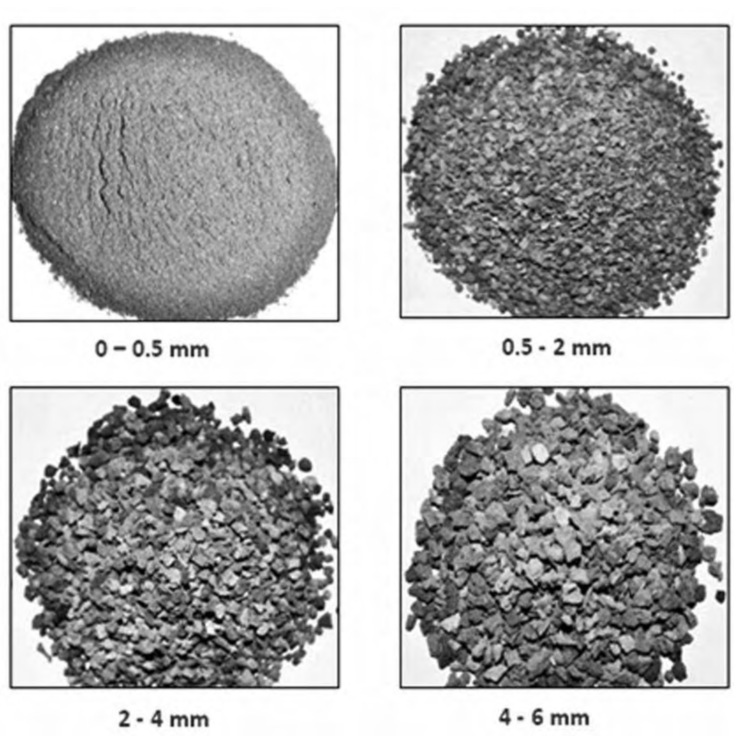

Fig 5: Screened granulated steel slag

3. Characterization of Granulated LD Slag

The visual observation of as received samples of GLDS series indicated that the colour of the material was black to grey with a varying lump size having sharp angular edges.

The chemical analysis (Table-1) shows the main constituent oxides as CaO, SiO_2, Fe_2O_3, Mn_2O_3, Al_2O_3 and MgO. The CaO and Fe_2O_3 content varied in a relatively larger range of 35 to 40 and 30 to 35 percent respectively as shown in Table 1. The other oxides such as SiO_2, Al_2O_3 and MgO varied relatively in narrow range. The SO_3 content was found nil in all the samples. The samples were subjected to trace element analysis using state of the art ICP and the results are presented in Table 2. The results obtained indicated that the various trace elements present in the GLDS samples were barium, beryllium chromium, copper, nickel and strontium only.

Table 1: Chemical Analysis of Granulated LD Slag

Oxide	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Na_2O	Mn_2O_3	CL	Sulphide S
%	10-13	30-35	2 - 5	35-40	4 -6	Nil	0.10-0.15	5 - 8	0.015 - 0.020	0.6 -0.7

Table 2: Concentration of trace elements present in Granulated LD Slag

Element	Ba	Be	Cd	Co	Cr	Cu	Ga	Ni	Pb	Se	Sr	Te	Th	Zn
	0.008	0.0006	Nil	Nil	0.043	0.001	NIl	0.001	Nil	Nil	0.014	NIl	Nil	Nil

Considering the Fe2O3 content in the various LD slag samples, it was considered appropriate to investigate the presence of magnetic material which could be separated in the samples. The exercise was carried out manually using a circular magnet. The results indicate that the yield of magnetic material in GLDS samples was low and varied in the range of 2.7 to 4.6 % This aspect was more important in view of further investigations for using these materials as replacement of sand in mortar.

The MODEL composition of granulated LD slag samples indicated that they contain glassy grains, semi glassy grains and quartz in the range of 51-56 %, 13-15 % and 7-10 % respectively. Minerals like hematite and magnetite were broadly in the range of 7-8 % each. The results of XRD investigation of GLDS series samples indicated that the major mineral phases in the sample were Manganosite followed by Srebrodolskite, Hematite, Wuestite and Larnite as shown in Figure 6.

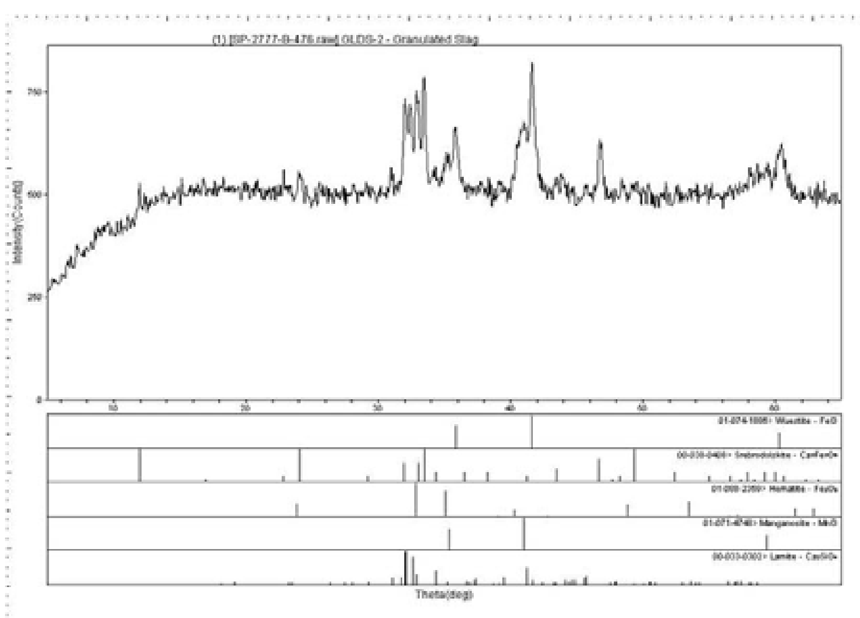

Fig 6: XRD pattern of Granulated Slag sample

The sieve analysis of granulated slag sample is given in Table 3, which indicate that GLDS samples conform to the size requirement as per IS:383 for fine aggregate zone –I.

Table 3: Sieve analysis of the granulated steel slag samples

Sieve Analysis, % passing	GLDS
10 mm	100
4.75 mm	100
2.36 mm	90
1.18 mm	45
600 micron	23
300 micron	10
150 micron	3

Table 4: Physical parameters of granulated steel slag samples

Parameters	GLDS
Specific Gravity	3.69
Water absorption, %	0.8
Silt %, wet sieving	1.5
Clay lumps	Nil
Organic impurities	Nil
Total deleterious material	Nil
LBD, kg/l	1.88
CBD, kg/l	2.07

LBD- loose bulk density
CBD-compact bulk density

The physical parameters such as specific gravity, water absorption and silt percent by wet sieving were found to be 3.48, 1.3 % and 10.33 % respectively. The detailed physico-chemical and mineralogical analysis of granulated LD slag established that material is suitable for replacement of fine aggregate.

4. Experimentation

100 kgs granulated steel slag samples were collected from the slag granulation unit for 5 days and were analyzed separately. All the samples have found to have almost similar characteristics therefore it was considered appropriate to mix all the samples and prepare one composite sample. Thereafter the representative samples were prepared and the same were used for relevant physical and chemicomineralogical analysis and mortar testing.

- **Preparation of Mortar samples**

The cement mortar samples were prepared using natural sand and replacing it gradually by steel slag. The replacement levels were 0, 25, 50, 75 and 100 % of natural sand.

- **Performance Evaluation of Mortar Samples**

These mortar samples were evaluated as per IS:4031 for workability, air content, density of mortar and compressive strength development. The results obtained are presented in Table-5

Sl. No.	Percentage of replacement of sand with GLDS	*workability (%)	*air content (%)	*density of mortar (g/cc)	# Compressive strength (N/mm^2)		
					3 days	7 days	.28 days
1	00	85	8.37	2.29	21.50	28.50	35.02
2	25	81	3.74	2.41	28.50	37.50	49.24
3	50	84	1.19	2.54	32.50	43.50	51.24
4	75	86	0.53	2.68	35.00	47.00	57.41
5	100	82	0.05	2.78	26.50	36.00	47.41

* IS:4031-part-12
\# IS:4031-part-6

- **Suitability of GLDS for use as replacement of Natural Sand**

The detailed physical, chemical and mineralogical investigations of various collected samples of GLDS were carried out to establish the suitability for replacing the natural sand used in mortar preparation. The chemical analysis indicated that GLDS contained chiefly CaO and Fe2O3 followed by SiO_2, Al_2O_3 and Mn_2O_3. The minerals present were Srebrodolskite, Manganosite ,Hematite, Wuestite, Larnite and Lime in varying order. The detailed microscopic investigations indicated that GLDS contained glass grains, semi glassy grains and quartz in the range of 51-56 %, 13-15 % and 7-10 % respectively. Minerals like hematite and magnetite are broadly in the range of 7-8 % each. The grain size distribution of glassy grains present in these samples indicates that ~ 60-70 % of the grains are less than 60 micron size. The glassy grains in granulated samples are relatively more fragmented as compared to that of ungranulated LD slag samples.

The above analysis indicated that GLDS is a potential material for use as fine aggregate replacing natural sand. The results of performance of mortar samples prepared replacing natural sand by GLDS by 0, 25, 50, 75 and 100 % indicated that the it was possible to replace the natural sand with GLDS and the 28 days compressive strength were found to be 35.02, 49.24, 51.24, 57.41 and 47.41 MPa respectively indicating that the compressive strength at 28th day is always more than that of control sample. The strength development was found to be maximum at 75 % addition of GLDS. At 100 percent replacement of natural sand with GLDS, the strength showed a downward trend but the same was still higher than that of control sample. Therefore, it was concluded that the 100 % granulated steel slag could be gainfully utilized as replacement of natural sand and mortar with improved Characteristics could be produced. The present work indicates that Slag is non hazardous, non toxic material, and is free of any impurities like silt clay etc. Slag sand, if used can stop mining of river sand and efforts must be made to consider slag sand as a Green Material in construction.

5. Conclusions

The steel industry is committed for recycling of slags generated during the steel production. While in the past steelmaking processes were exclusively designed for the production of specific qualities of iron and steel, one of the today's goals for steelmakers is to design processes to produce high quality slags, according to the market requirements. New technologies and/or the improvement of existing technologies have been investigated and developed in order to achieve the ambitious target of "zero-waste" in the incoming years. Granulated steel slag is an ideal example to convert a waste in to an usefull product which can help in conserving the river sand. Granulated steel slag provides an eco-friendly alternative to river sand. The performance of mortar samples prepared replacing natural sand by granulated steel slag indicated that it is possible to replace the natural sand with granulated steel slag. Granulated steel slag could be gainfully utilized up to 100 % as replacement of natural sand in cement mortar preparation and mortars with improved performance characteristics could be produced.

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Use of Copper Slag as Fine Aggregate in Concrete

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1. INTRODUCTION

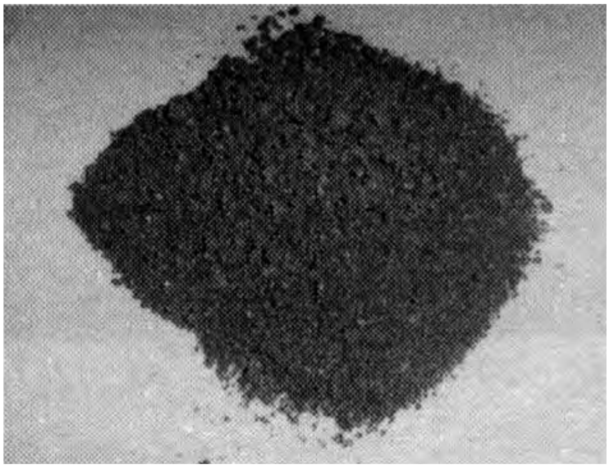
Every year large quantities of different industrial by-products are being produced by various industries and governments are seeking ways to reduce the dual problem of disposal and health hazard from the accumulation of by-products. Some of these by-products, such as, fly ash, ground granulated blast furnace slag and silica fume are already being used to produce high value concrete. Since, construction industry is already facing a scarcity of source materials from natural resources, such as, sand and stone aggregate and some of the source materials, such as, cement are highly energy intensive, the utility of industrial wastes will go a long way in promoting sustainable development of construction industry.

Copper slag, which is by-product of the manufacture of copper, is one of the promising industrial by-products. This slag is currently being used for many purposes ranging from land-filling to grit blasting, which are not very high value added applications. These applications utilise only about 15% to 20% of the copper slag generated and the remaining material is dumped as a waste, which requires large areas of land. Alternative use of it as partial or complete substitute for fine aggregates has been attempted. Presently the copper slag is mainly available at Sterlite Industries Ltd-Tuticorin, Biria copper- Dahej and Hindustan copper -Jharkand. There is stock of about 8 million tonnes and about 6000 tonnes is getting added every day.

2. WHAT IS COPPER SLAG?

Copper slag, which is byproduct of the manufacture of copper, is one of the promising industrial byproducts. To produce every ton of copper, approximately 2.2-3.0 tons copper slag is generated as a by-product material.

Photo view of slag



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2.1 Specification of Slag

Physical properties particularly "grading" of copper slag of Sterlite Industries at Tuticorin Project are given in Table 1 below.

TABLE 1 Physical properties of copper slag

Specific gravity (SSD)[1], 4.12g/cc, (Normal Range : 3.8 to 4.2) Bulk density (SSD): 2.31 gm/cc Fineness modulus: 2.701, Deleterious Materials: Not present

Weigh: 2000 g		Sieve analysis			
IS Sieve No	Wt retained gm	% Retained, gm	Cumulative % Wt Retained	Cumulative % Passing	Acceptable Limit of passing as per Spec/ IS383
10 mm	0	Nil	Nil	100	100
4.75mm	11	0.55	0.55	99.45	90 to 100
2.36mm	73	3.65	42.2	95.80	75 to 100
1.18mm	385	19.25	23.45	76.55	55 to 100
600 microns	638	31.90	55.35	44.65	35 to 60
300 microns	681	34,05	89.40	10.60	5 to 30
150 microns	151	7.8	97.20	2.8	0 to 10
% Passing	56	2.8	100	0	-
					2.3 to 2.6 Fine Sand
					2.6 to 2.9 Medium
					2.9 to 3.2 Coarse sand
Fineness Modulus		2.701			

SSD - Saturated surface dry

2.2 Chemical Composition of Copper Slag

Chemical composition of copper slag as reported by the Sterlite Ltd., Tuticorin is given Table 2.

TABLE 2 Chemical properties of copper slag

Composition	% by mass
Fe_2O_2	55 - 60%
Fe_3O_4	<10%
SiO_2	27 - 33%
CaO	1 - 3.5%
S	0.2 - 1.5%
Cu	< 1%
Al2O3	< 3%

1.3 Mix Design for Pumpable Concrete

The mix proportions of the control concrete mixes with 100% river sand, which were used for this study, are given in Table 3. These basic mix proportions were modified for using copper slag as a partial replacement for sand. The mixes were proportioned for aggregates by the method of absolute volumes considering the specific gravity of the constituent materials. The trial was carried out to replace 50% of sand with copper slag. Since cement content was low and fines below 600 microns were low it was decided to use flyash as additional fines and part replacement of cement.

TABLE 3 Computed proportions of control concrete mixes.

Mix proportions

Grade	Cement	Sand	10 mm Agg.	20 mm Agg.	Water	w/c ratio	Admixture
M20	300	882	431	647	175	0.55	2.24
M25	320	861	421	631	186	0.55	2.24

Testing

To determine the compressive strength. Eight cubes (150 mm x 150 mm x 150 mm) were cast for each mix, and three samples each were tested after 7 and 28-days of curing. 7 and 28day cube compressive strength test was conducted in accordance with IS: 516-1959 All strength tests were conducted using 2000kN compression testing machine.

2.4 Photograph of Trial Mix Done at Site

Cu slag concrete after 30 min.

TABLE 4 Computed proportions of Trial mixes

Sl. No	Description	Trial Mix - A	Trial Mix - F	Trial Mix- H
1	Grade of Concrete	M25	M25	M25
2	Cement (kg)	320	300	280
3	Fly Ash (kg)	0	100	120
4	Ferro Sand (Slag) (kg)	0	620	620
5	Coarse Aggregate 20 mm (kg)	631	616	616
6	Coarse Aggregate 10 mm (kg)	421	410	410
7	Fine Aggregate (Kg)	861	443	443
8	Water (Lit)		186	186
9	Admixture (Lit)		2.24	2.24

Note: Trial mix F has more cementatious content (25% more) though less cement content than trial mix A. This is partly responsible for higher strength of Mix F- compared to mix A (Table 5 below)

TABLE 5 Properties of concrete after 7- and 28-days of curing

Slump - 0 min	155 mm	135 mm
Slump - 30 min	135 mm	80 mm
Strength - 7 days	37 N/mm^2	40N/mm^2
Strength - 28 days	45N/mm^2	56N/mm^2

Note: The were done at SERC laboratory, Chennai

2.5 Mix Design and Sample Preparation

The mix proportions of the control concrete mixes with 100% river sand, which were used for this study are given in Table 6. These basic mix proportions were modified for using copper slag as a partial replacement for sand. Fifteen concrete mixes with different proportions of copper slag ranging from 0% (for the control mix) to 100% were considered. All the mixes were proportioned by the method of absolute volumes considering the specific gravity of the constituent materials. The materials were weighed using a digital balance. The materials were mixed in a pan mixer. The mixes were compacted using vibrating table. The slump of the fresh concrete was determined to study the effect of copper slag replacement on the workability of concrete. The specimens were demoulded after 24 h, cured in water and then tested in saturated, surface dry condition at the required age.

TABLE 6 Computed proportions of control concrete mixes

Mix proportions

	Cement	Sand	10 mm Agg.	20 mm Agg.	Water	w/c ratio
CCI	450	784	384	576	180	0.4
CCII	413	788	384	576	190	0.46
CCIII	346	843	384	576	190	0.55

Testing

To determine the compressive strength, eight cubes (150 mm x 150 mm x 150 mm) were cast for each mix, and four samples each were tested after 7 and 28-days of curing. 7 and 28day cube compressive strength test was conducted in accordance with IS: 516-1959. All strength tests were conducted using 2000kN compression testing machine.

Effect of Copper Slag on the Workability and Density of Concrete

It is clear from Table 7 that the workability of concrete increases, at low percentage (25%) of replacement of natural sand by copper slag but by increase in replacement of natural sand by copper slag, it decreases. But even with 100% replacement by copper slag, slump obtained is more than that with 100% natural sand. This increase in the workability with the copper slag is attributed to the low water absorption characteristics of copper slag. This increase in the workability may have beneficial effect on concrete in the sense that mixes with low water-to-cement ratios, for the same amount of sand replaced, concrete can be produced which may have good workability, greater strength than the conventional concrete. However, it should be noted that mixes with high contents of copper slag (i.e. Mixes 5, 10 and 15) showed signs of bleeding and segregation which can have detrimental effects on concrete performance. But this problem can be easily overcome by the addition of finer materials such as fly ash, quarry dust, which are also incidentally industrial wastes. In the present study, all the mixtures were prepared without using superplasticizers. The slump values obtained for the mixes indicate that they require much less dosage of superplasticier to achieve the workability required for a pumpable concrete as in case of ready mix concrete. The slump retention, another major requirement of ready mix concrete, would also be better in view of the higher initial workability.

In general there is an increase in the density of concrete with the increase of copper slag quantity. The density of concrete was increased by 9-22%. This is mainly due to the higher specific gravity of copper slag The increased density of concrete mix should be taken into account in the design of formwork when it is to be used for structural applications.

Effect of Copper Slag on the Strength of Concrete

The average 7 and 28 day compressive strengths for different concrete mixes are shown in Fig.1 The expected target strengths are 31.6 MPa for M25 grade concrete and 48.25 MPa for M40 grade concrete assuming standard deviations of 4 MPa and 5 MPa, respectively vide Table 8 of 15:456-2000. These values are assured in the absence of sufficient experimental ts to evaluate the standard deviation. It is seen from Table 7 and Fig. 1 that the mixes 3 and mixes 11 to 12 are marginally short of the target strength while all the remaining meet the strength requirement. This may be attributed to the lower cement strength and higher than normal standard deviation used for determining the target strength. In actual practice, the standard deviation is likely to be much less when the sample size is larger and quality control is better.

TABLE 7 Properties of concrete after 7-and 28-days of curing

Mix no.	Mix Id	Mix Type	Fresh concrete Density [kg/m^3]	Slump (mm)	Strength (MPa)	
					f_c7	f_c28
1	CCI	Control (100% S)	2430	20	31	44
2	$CU_{25}I$	25% CS + 75% S	2612	85	33	47
3	$CU_{50}I$	50% CS + 50% S	2670	75	34	46
4	$CU_{75}I$	75% CS + 25% S	2790	60	37	50
5	$CU_{100}I$	100% CS	2923	40	38	52
6	CCII	Control (100% S)	2411	25	25	35
7	$CU_{25}II$	25% CS + 75% S	2624	85	26	41
8.	$CU_{50}II$	50% CS + 50% S	2696	110	28	43
9.	$CU_{75}II$	75% CS + 25% S	2818	85	27	40
10.	$CU_{100}II$	100% CS	2920	35	26	41
11.	CCIII	Control (100% S)	2405	25	17	25
12.	$CU_{25}III$	25% CS + 75% S	2620	150	18	27
13.	$CU_{50}III$	50% CS + 50% S	2711	65	21	29
14.	$CU_{75}III$	75% CS + 25% S	2815	45	21	31
15.	$CU_{100}III$	100% CS	2940	30	20	30

f_c = cube compressive strength, S = sand, CS = copper slag. Co_{25}, Cu_{75} respectively refer to mixes with copper slag 25% (natural sand 75%) And copper slag 75% (Natural sand 25%), etc. f_{C7}. cube compressive strength. Cured for 7-days. f_{C28} - cube compressive strength, Cured for 28-days.

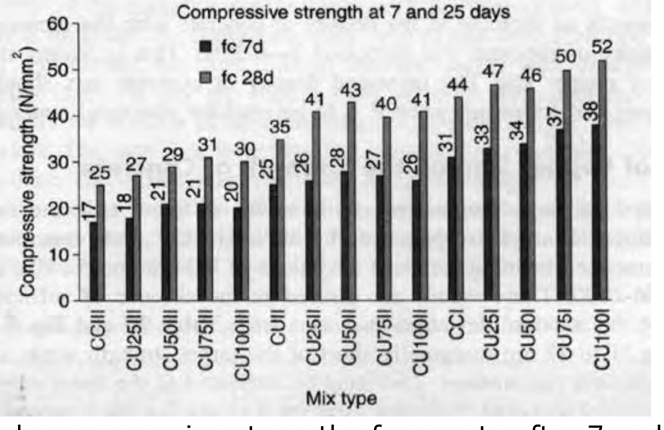

Fig. 1 Average cube compressive strength of concrete after 7 and 28 days of curing.

The results also show that the compressive strength of copper slag concrete is increase when compared to control concrete (around 24%), where as copper slag quantity increases the strength is often more or less same.

As in the case of control concrete, for copper slag concrete when the water cement ratio increases the strength reduces. As seen from Fig. 2, irrespective of water-cement ratio, as the copper slag content increases, the compressive strength increases. The highest compressive strength was achieved by Mix 5 (Table. 7) with 100% replacement of copper slag, which was found about 52 MPa compared with 44 MPa for the control mixture. The increase in the strength was 18% compared to the control mix. However, the increase in compressive strength copper slag based concrete over control concretes was almost of the same order for all copper slag contents investigated in the study. Therefore, if the concrete mixes are proportioned by absolute volume method and the percentage of replacement of river sand is by mass of the total fine aggregate, the compressive strength is influenced mainly by the water-cement ratio. The we observations are supported by the work of other researchers who studied the influence of copper slag as fine and coarse aggregates on the strength of both normal and high-strength Concrete. The results indicated that the compressive strengths of concrete made with copper slag are slightly higher than that of the control mixtures. The compressive strength of mortars and concrete specimens containing copper slag as fine aggregate was investigated by Hwang and Laiw (1989) and the study concluded that the mortars containing the larger amounts of apper slag with 20%-80% substitution of copper slag as fine aggregate had the strengths higher) than that of the control specimens. Investigations conducted by Khanzadi and Behnood (2009) also showed that the use of copper slag aggregate compared to limestone aggregate resulted in a 28-day compressive strength improvement of about 10%-l5%. Therefore, copper slag can be beneficially used as partial replacement for river sand in concrete construction for normal structural grade concrete (M20-M40). Since the rate of strength development and the strength at 28 days are satisfactory and generally better than that of concretes with conventional sand, copper slag can be used in the ready mix concrete with no significant modifications in the production process and the performance would meet all the necessary requirements.

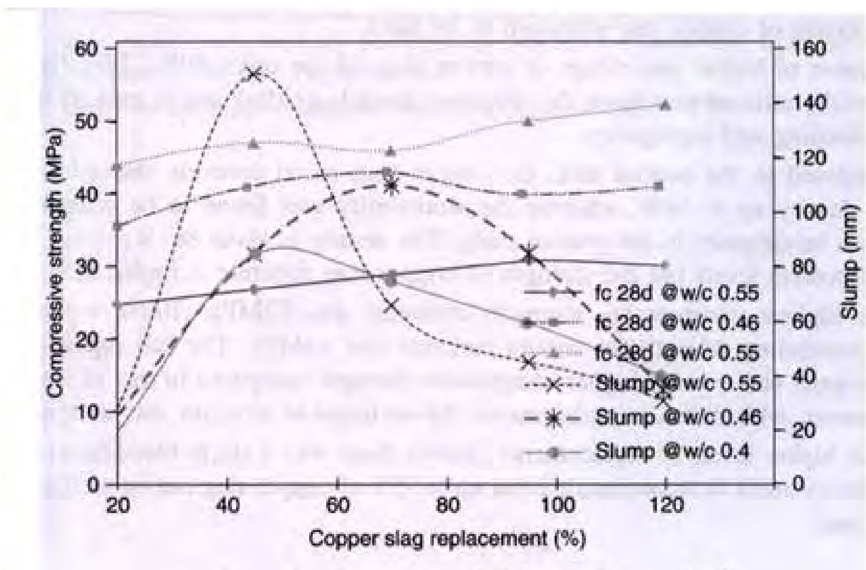

Fig. 2 Relationship between workability and strength of concrete

Durability Studies by CECRI

Various tests like strength, chloride diffusion, open circuit potential measurement and macro potential measurement and macro cell corrosion studies were conducted .Chloride diffusion tests as per ASTM C-1202 shows copper slag mortar results are similar to sand. CECRI recommended that copper slag can be used as sand.

Experiences in Singapore

This can be best summarized in words of Dr. Ghosh (2010) which reads as “By the middle of 2006, after extensive testing and development, we had a product that was not only a substitute for sand, but, in fact, was a far superior substitute for sand.’The real battle, however, lay ahead, Dr Ghosh had to convince the industry, the regulators and the end-users. It was not easy. “Most give up here. Eventually, the uphill battle was won, somewhat facilitated by the subsequent sand-ban from Indonesia in 2007 which made people think seriously about resource recovery and reuse, and the eventual support provided by the Building and Construction Authority (BCA), to help promote this alternative to sand. It gives me a great sense of self-satisfaction when I hear these days that no copper slag sand is sent to landfills and the material is in high demand as builders get 'green points' from BCA for using concrete that is made with copper slag sand as a partial substitute for natural sand," says Dr Ghosh, with justifiable pride. (Ref. 8)

3 CONCLUDING REMARKS

The following conclusions may be drawn from the present study:

1. The behaviour of copper slag seems to be similar to river sand for its use as fine aggregate in mortar and concrete mixes. However minor adjustment/modifications may have to be made in view of the higher specific gravity and rough surface texture and the extent of copper slag proposed to be used.
2. In cases of higher percentage of copper slag (of the order 50%-75%), fly ash may be gainfully utilized to achieve the necessary particle grading and to exclude the possibility of bleeding and segregation.
3. Compared to the control mix, the copper slag based concrete showed an increase in the density up to 19%, whereas the workability was found to be often better for the mixes investigated in the present study. The density is about 8to 9 percent more at 50% replacement levels but the strength of copper slag concrete is higher (15% to 25%).
4. The highest compressive strength obtained was 52MPa (100% replacement), the corresponding strength for control concrete was 44MPa. The full replacement of sand by copper slag yielded higher compressive strength compared to that of the control mix, However, with different replacements the variation in strength was marginal.
5. With higher levels of replacements (100%) there was a slight bleeding and segregation tendency and it is recommended that up to 75% of copper slag can be used as replacement of sand.
6. The use of copper slag as partial replacement for sand in ready mix concrete is beneficial of the better workability and strength without danger of segregation which does not occur generally upto 50% replacement level. Such applications are already reported in other countries. It has been found to be suitable for the production of self compacting concrete in a few studies.
7. The experience in the present study indicates that up to 50% of the fine aggregate can be made up of copper Slag and the rest can be made up of conventional sand. However, the actual content of copper slag depends upon the grade of concrete and the fineness modulus of sand available for use in concrete.

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Study on Use of Manufactured Sand in Self-Compacting Concrete

Dr. R. Nagendra and Dr.H Sharada Bai

INTRODUCTION

With the restrictions on dredging of river sand imposed in different parts of the country since 2010, ,manufactured sand is being increasingly used in concrete production under several trade names such as crushed sand, rock sand, green sand, robo sand, e-sand etc. IS 383-1970 (Reaffirmed 2007) [1] recognizes manufacture sand as 'crushed stone sand' under Clause 2.

Crushed stone sand is produced by crushing boulders. Manufactured sand is produced by rock-on-rock or rock-on-metal vertical shaft impactor (VSI) in which the process that produced alluvial deposits is closely simulated. Particle size reduction and achieving equidimensional shape is critical to get desired properties. If rock is crushed in compression lot of inherent properties exhibited by natural river sand are lost. If proper technique of manufacturing is not adopted aggregates are bound to become flaky and elongated. Improvements to sand by way of washing, grading and blending may have to be done before use at the consumer end. In case of manufactured sand all the processes mentioned above can be done at manufacturing plant itself and controls are much better in producing quality fine aggregates.

In this paper, study conducted on Self-Compacting Concrete (SCC) made with manufactured sand from four different vertical shaft impact crushers is presented. SCC mixtures have lower total aggregate content in the mix as compared to conventional concrete. Also, they have greater fine aggregate content relative to coarse aggregate. Key characteristics of aggregate which affect rheology of SCC are maximum size, shape, texture, angularity and gradation. A proper understanding of characteristics of aggregates becomes handy for predicting flow properties of SCC.

LITERATURE SURVEY

Several researchers have studied the effect of aggregates on properties of self-compacting concrete. Some of these studies done in recent times are only mentioned.

The mixture proportioning method developed by Su et al. [2] consists of selecting the aggregate volume and then filling the voids between aggregates with paste of the appropriate composition. The masses of coarse and fine aggregates in concrete are increased by a packing factor (PF), which reflects the increase in packing density of the aggregates in actual concrete mixtures. Su et al. showed that increasing the packing factor resulted in a lower paste volume with a higher w/cm and a lower concrete strength.

Investigations conducted by Prakash Nathagopalan and Manu Santhanam [3] to explore the possibility of 100% replacement of river sand by using manufactured sand indicated that the presence of high fines in manufactured sand increases the water demand and these fines contribute to an increase in paste volume, which is useful for the development of SCC. The powder and aggregate combinations were optimised by using packing density criterion. Experimental results revealed that paste volume had a predominant effect on the fresh concrete properties for a given combination of aggregates. A minimum of 160 L of water and 70–90 L of excess paste (per cubic metre of concrete) over and above the void content of the aggregates was found essential for achieving SCC with a slump flow of 550 mm. Though the paste volume required for SCC with manufactured sand is relatively higher than SCC with river sand, the paste volume contributed by the high fines content of manufactured sand compensates this requirement

According to an analysis of 68 SCC case studies conducted by Domone [4], mixture proportions for SCC vary widely such that there is not a unique solution for any given application. The analysis found that coarse aggregate contents varied from 28 to 38% of concrete volume, paste content varied from 30 to 42% of concrete volume, powder content ranged from 445 to 605 kg/m^3, water-powder ratio ranged from 0.26 to 0.48, and fine aggregate content varied from 38 to 54% of mortar volume.

RESEARCH SIGNIFICANCE

A study of alternative to river sand is the need of the hour. Self-compacting concrete is very sensitive to properties of fine aggregates which directly affect the quality paste. In this research work, manufactured sand sourced from three different vertical impact crushers is considered as an alternative to river sand. Micro fines present in manufactured sand is expected to improve the packing density thus reducing the paste requirements to achieve flow properties of self-compacting concrete. Reduction in paste volume is also expected to improve both strength and durability properties of self-compacting concrete.

TESTS ON FINE AGGREGATES

This research focuses mainly on the use of manufactured sand vis-à-vis natural river sand in SCC .

Fine aggregates used in this investigation are of following two types:

a) Natural River Sand (NRS) sourced from Sakaleshpur

b) Manufactured Sand (M-sand)

Manufactured sand from the following three VSI crushers is used for investigations.

1. VSI-1 Fine aggregates from VSI crusher of Puzzolana make
2. VSI-2 Fine aggregates from VSI crusher of Proman make
3. VSI-3 Fine aggregates from VSI crusher Barmac make

Natural river sand and manufactured sand are tested for gradation, loose and rodded bulk density, specific gravity, water absorption and particles finer than 75 µm as per IS 2386 (Parts 1 & 3). [5,6]. Sieve analysis test results conducted on fine aggregate are plotted in Figure 1.

Table 1 Gradation of Fine Aggregate

IS Sieve size	Cumulative percent passing				Requirement as per IS 383-1979 (Reaff.2007) Grading Zone-II
	Natural River Sand	Manufactured Sand			
	Sakaleshapur	VSI-1	VSI-2	VSI-3	
4.75mm	97.2	99.7	100	99.8	90-100
2.36 mm	92.7	84.8	83.8	77.8	75-100
1.18 mm	78.6	67.7	63.8	60.3	55-90
600µm	42.0	50.6	47.9	47.9	35-59
300µm	11.7	28.6	28.1	28.9	8-30
150µm	0.7	9.0	11.0	9.3	0-10

Note: For M sand, requirement of cumulative percentage passing through 150 microns is 0-20 as per IS 383-1970 (Reaff .2007)

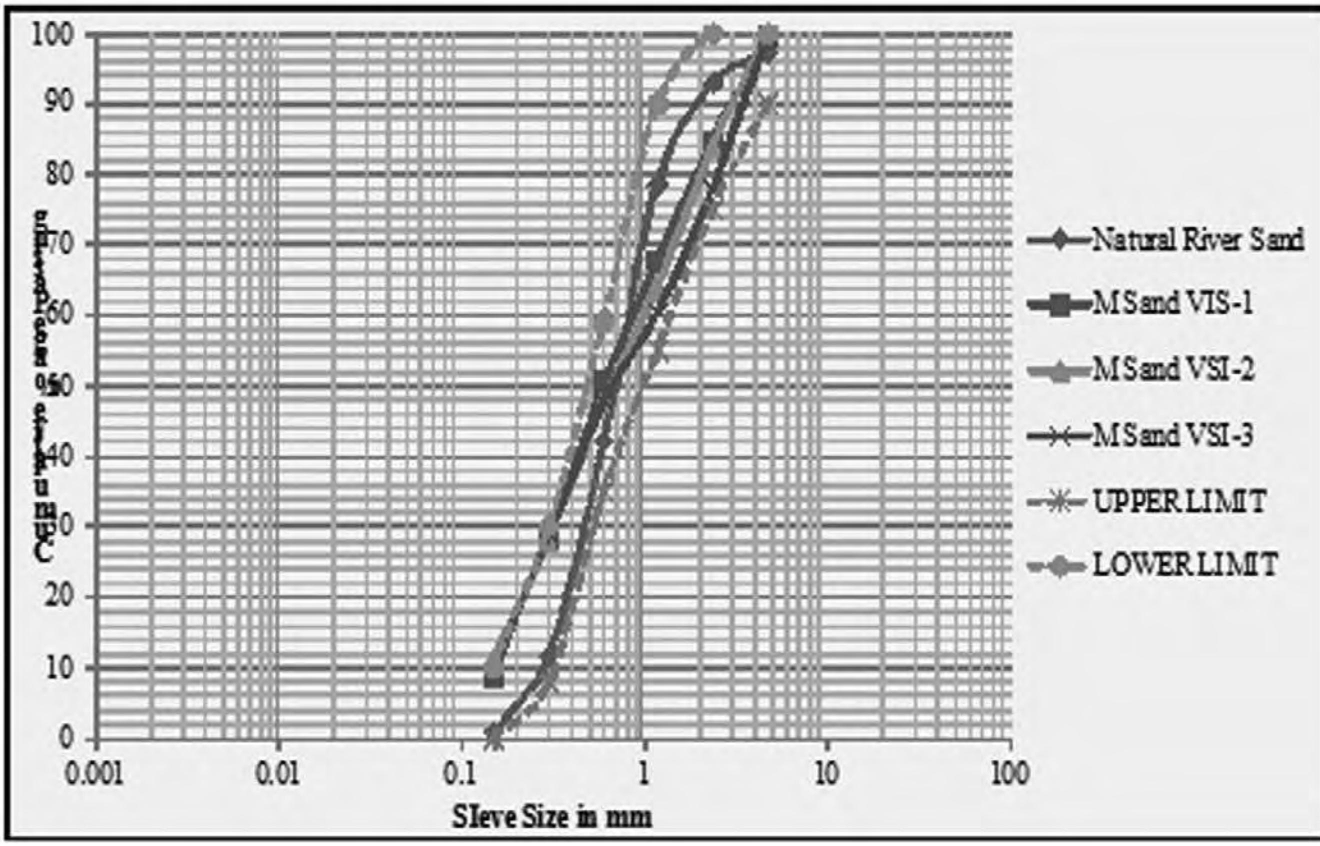


Fig. 1 Sieve Analysis of Natural River Sand and M Sand

Table 2 Physical Properties of Fine Aggregates

Property	Natural River Sand	Manufactured Sand			Requirement as per IS 383-1979 (Reaff.2007)
	Sakaleshapur	VSI-1	VSI-2	VSI-3	
Materials finer than 75 μm	1.8	10.6	11.2	9.5	Max 3% for NRS and 15% for M-sand
Specific Gravity	2.63	2.65	2.66	2.66	-
Water Abortions	2.5%	3.5%	3.6%	3.7%	-
Loose Bulking Density kg/m^3	1618	1787	1760	1752	-
Rodded Bulking Density kg/m^3	1750	1977	1828	1899	-

Coarse aggregates from VSI crushers: Coarse aggregates from three different VSI crushers are sourced for investigation. They are given below:

1. VSI-1 aggregates from VSI crusher of Puzzolana make
2. VSI-2 aggregates from VSI crusher of Proman make
3. VSI-3 aggregates from VSI crusher of Barmac make

Table 3 Sieve Analysis of coarse aggregate

IS Sieve Designation (mm.)	Cumulative Percentage passing						Specifications as per 383-1970 (Reaff. 2007) (%)	
	20 mm			12.5 mm				
	VSI-1	VSI-2	VSI-3	VSI-1	VSI-2	VSI-3	Graded	Single size
20	96	91	90	100	100	100	95-100	85-100
12.5	4.2	2	6	98.6	99.4	97.4	--	--
10	0.2	0	0	62.2	76.9	62.0	25-55	0-20
4.75	0	0	0	0.6	0.5	0.0	0-10	0-5

Table 4 Physical properties of coarse aggregate sample

Sl No	Sample	Sp Gr	Flakiness Index (%)		Elongation Index (%)		L.B.D kg/m^3**		R.B.D kg/m^3***	
			12.5 mm	20.0 mm	12.5 mm	20.0 mm	12.5 mm	20.0 mm	12.5 mm	20.0 mm
1	VSI-1	2.65	2.5	4.1	2.2	4.2	1495	1520	1613	1617
2	VSI-2	2.66	2.3	3.8	2.5	3.5	1438	1441	1525	1574
3.	VSI-3	2.66	2.7	4.3	2.1	4.2	1439	1413	1525	1574

Sp Gr*=Specific Gravity, L.B.D**=Loose Bulk Density, R.B.D***=Rodded Bulk Density

Determination of optimized quantity of aggregates:

The following procedure is adopted to determine the quantity of aggregates for the optimized condition.

Calculation of Quantity of aggregates:

Let Vfa and Vca be the loose volumes of fine aggregates and coarse aggregates respectively in a unit volume. Let ρ_{fa} and ρ_{ca} represent loose densities of fine and coarse aggregates respectively.

Let $R_{fa/ta}$ be the percentage fraction of fine aggregate in total aggregate mass.

We have, loose mass of fine aggregates $m_{fa} = V_{fa} \times \rho_{fa}$ and

loose mass of coarse aggregates $m_{ga} = V_{ca} \times \rho_{ca}$

Volume of aggregates as discussed above has been represented in the Figure 2 given below:

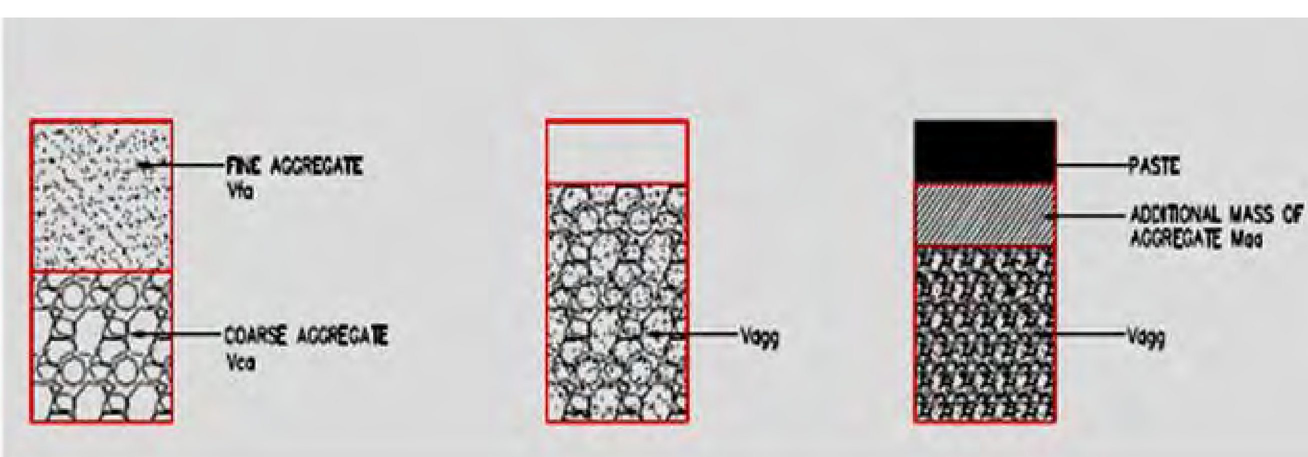


Fig. 2 Schematic diagram of constituents of SCC

$$Vfa + Vca = 1$$ ------------- Equation 1

$$\frac{Vfa \times \rho fa}{Vfa \times \rho fa + Vca \times \rho ca} = R_{fa/ta}$$ ------------- Equation 2

Packing factor (PF): In this study, PF is calculated by choosing the value corresponding to the optimum ratio of sand to aggregate ($R_{fa/ta}$). The compacted bulk density and loose bulk density of the aggregates at the point of optimum ratio ($R_{fa/ta}$) are therefore initially found, and PF can be computed as follows:

Aggregate packing factor (PF) is defined as the ratio of optimized rodded bulk density (R.B.D.) of combined aggregates to optimized loose bulk density (L.B.D.) as determined above.

$$PF = \frac{R.B.D}{L.B.D}$$

Mass of total aggregate (M_{agg}):

$$Magg = PF\,(mfa + mca)$$
$$= PF\,(Vfa \times \rho fa + Vca \times \rho ca$$

The additional mass of aggregates $Maa = (PF - 1)\,(mfa + n$

Packing density: Packing density of aggregates is calculated by dividing optimized mass of total aggregates by its specific gravity.

$$Mass\ of\ fine\ aggregate\ Mfa = PF \times (Vfa \times \rho fa)$$

$$Mass\ of\ coarse\ aggregate\ Mca = PF \times (Vca \times \rho ca)$$

$$Total\ volume\ of\ aggregates = \frac{Mfa}{SGfa} + \frac{Mca}{SGca}$$

Volume of paste: Volume of paste is calculated by deducting packing density from unit volume of concrete.

$$Volume\ of\ paste\ Vp = 1 - Total\ volume\ of\ aggregates$$

$$Volume\ of\ Paste\ Vp = 1 - \left(\frac{Mfa}{SGfa} + \frac{Mca}{SGca}\right)$$

Volume of paste: Volume of paste is calculated by deducting packing density from unit volume of concrete.

OPTIMIZATION OF AGGREGATES

Optimization of aggregates is done in two stages. The first stage consists of optimizing coarse aggregates of two sizes viz. 20 mm and 12.5 mm and the second stage consists of optimizing fine aggregates and coarse aggregates. Both loose and rodded density of combined coarse aggregates (20 mm and 12.5 mm) was determined experimentally by varying the mass ratio of 12.5 mm to total coarse aggregates from 0% to 100% at an interval of 20%. The ratio of mass of 12.5 mm to total aggregate which gives maximum rodded bulk density is considered for second stage optimization. Both loose and rodded density of combined aggregates (coarse aggregate and fine aggregate) was determined experimentally by varying the mass ratio of manufactured sand to total aggregates from 0% to 100% at an interval of 10%. Bulk densities of combined aggregates are graphically represented in Figures 3 & 4

Packing Factor, Packing Density and Volume of Paste calculated using the equations above are shown in Tables 5 & 6.

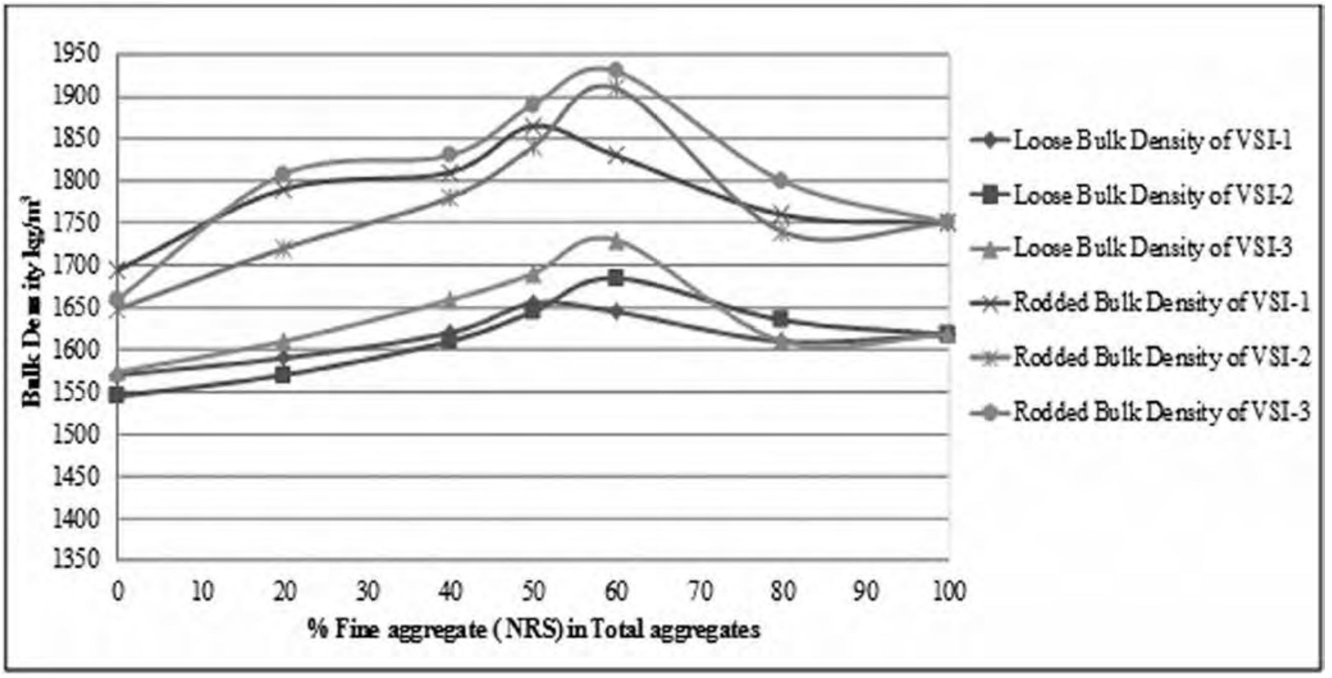


Fig. 3 Bulk density of combined aggregates (20 mm,12.5 mm size & Fine aggregate) v/s % Fine aggregate (Natural River Sand) in Total aggregates

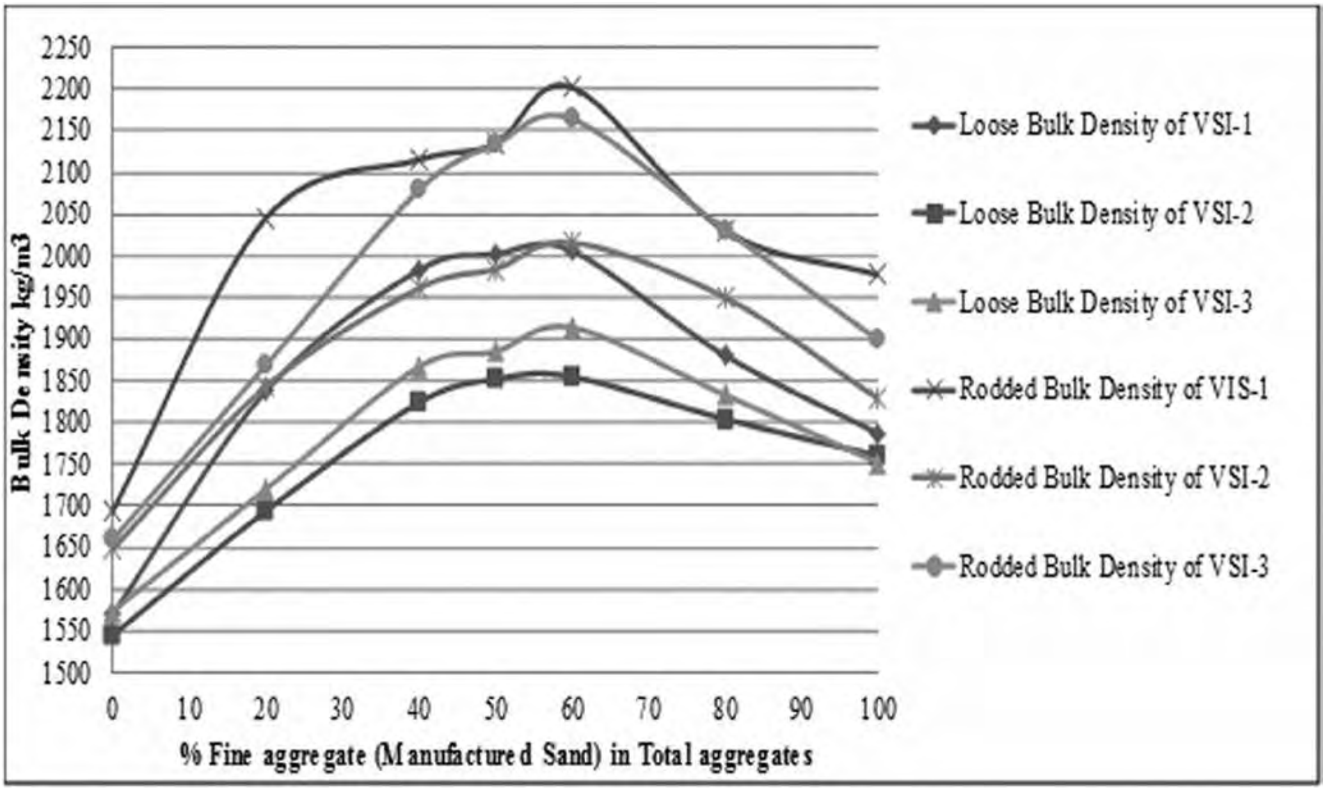


Fig.4 Bulk Density of combined aggregates (20 mm,12.5 mm size & Fine aggregate) v/s % Fine aggregate (Manufactured Sand) in Total aggregates

Table 5 Packing Factor, Packing Density and Volume of Paste with Manufacture Sand

Aggregate Source	Optimized proportion FA in TA	Optimized LBD kg/m^3	Optimized RBD kg/m^3	Packing factor PF	Packing density	Volume of paste
VSI-1	0.57	2006	2202	1.10	0.699	0.301
VSI-2	0.58	1855	2016	1.09	0.679	0.321
VSI-3	0.60	1914	2164	1.13	0.713	0.287

Table 6 Packing Factor, Packing Density and Volume of Paste with Natural River Sand

Aggregate Source	Optimized ratio of FA in TA	Optimized LBD kg/m^3	Optimized RBD kg/m3	Packing factor PF	Packing density	Volume of paste
VSI-1	0.52	1655	1865	1.13	0.681	0.319
VSI-2	0.62	1685	1910	1.13	0.682	0.318
VSI-3	0.57	1730	1930	1.12	0.675	0.325

Tables 5 and 6 gives details of Optimized proportion of fine aggregate in total aggregate, Optimized loose bulk density, Optimized rodded density, Packing Factor, Packing Density and Volume of Paste with Natural River Sand and M-sand respectively. Calculations for packing factor, packing density and volume of paste are explained earlier.

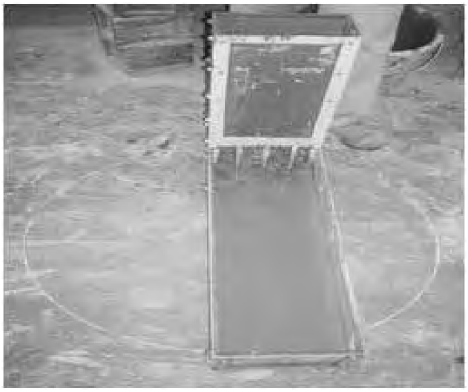
DETAILS OF SCC MIXES AND COMPRESSIVE STRENGTH TEST RESULTS

Based on the packing density approach explained earlier, SCC mixes are proportioned for cementitious contents of 400 kg/m^3, 450 kg/m^3, 500 kg/m^3, and 550 kg/m^3 with paste contents of 0.323, 0.341, 0.359 and 0.377 respectively. The total water content of 180 kg/m3 and cement replacement with flyash at 30% is adopted for all trials. Minimum volume of paste required to fill up voids between the aggregates depends on packing density of combined aggregates. Optimized packing densities for a particular source of coarse aggregates vary depending on whether NRS or M-sand is used as fine aggregates. Ordinary Portland cement of 53 grade conforming to IS 12269-1987 (RA 2008) and Pulverised fuel ash or flyash conforming to IS 3812-2003 (Part 1) are used for all trials. Mixing water used during trials was conforming to the requirements of suitability for concreting as per IS 456-2000. Poly Carboxylic Ether (PCE) based superplasticiser conforming to the requirement of IS 9103-1999. Details of trials carried out are shown in Table 7 for VSI-1 aggregates (Typical). Flow properties in terms of slump flow and V-funnel time are shown in Tables 8 & 9. Compressive strength at various ages and comparative compressive strength are shown in Tables 10 & 11 respectively.

Table 7 Mix proportions and fresh properties of SCC using VSI-1 aggregates

Mix Designation	SCC 400		SCC 450		SCC 500		SCC 550	
	NRS	M-Sand	NRS	M-Sand	NRS	M-Sand	NRS	M-Sand
Cement kg/m^3	280	280	315	315	350	350	385	385
Flyash kg/m^3	120	120	135	135	150	150	165	165
Fine aggregate kg/m^3	934.4	1055.4	917.8	1036.2	901.2	1016.9	884.7	997.7
Coarse aggregate 20 mm kg/m^3	517.5	477.7	508.3	469	499.1	460.3	490	451.6
Coarse aggregate 12.5 mm kg/m^3	345	318.5	338.9	312.7	332.8	306.9	326.6	301.1
Water kg/cu.m	180	180	180	180	180	180	180	180
Super plasticiser kg/m^3	4.8	4.4	4.5	4.1	4.0	3.5	3.8	3.4
Theoretical Density	2377	2432	2395	2448	2413	2464	2431	2480
Minimum paste required	0.319	0.301	0.331	0.314	0.343	0.327	0.355	0.339
Actual Paste provided	0.323	0.323	0.341	0.341	0.359	0.359	0.377	0.377

Ratio of water to binder w/b	0.45	0.45	0.4	0.4	0.36	0.36	0.33	0.33
Packing factor	1.13	1.1	1.11	1.08	1.09	1.06	1.07	1.04
SCC fresh properties								
Slump flow (mm)	550	600	610	700	650	725	675	750
T500 sec.	8	8	7	5	7	5	6	6
Slump flow of J ring	520	575	595	680	620	695	645	735
L- Box Ratio	0.75	0.9	0.8	0.9	0.8	0.95	0.85	1
V-funnel time	15	8	13	7	10	6	8	8



Photographs of fresh concrete tests on SCC

Table 8 Slump flow values for different types of aggregates for various paste contents

Aggregates Types	Slump Flow in mm of NRS for various paste contents				Slump Flow in mm of M-sand for various paste contents			
	0.323	0.341	0.359	0.377	0.323	0.341	0.359	0.377
VSI-1	550	610	650	675	600	700	725	750
VSI-2	620	570	670	700	590	600	610	630
VSI-3	570	600	620	650	650	730	750	760

Table 9 V-funnel time for different types of aggregates for various paste contents

	V-Funnel time in sec with NRS				V-Funnel time in sec with M-sand			
Type of aggregates	0.323	0.341	0.359	0.377	0.323	0.341	0.359	0.377
VSI-1	15	13	10	8	8	7	6	8
VSI-2	8	13	6	5	12	7	6	8
VSI-3	12	10	8	8	7	7	6	4

Table 10 Strength properties of SCC using VSI aggregates

Mix Designation		Cement kg/m³	Flyash kg/m³	Compressive Strength MPa											
				3-days			7-days			28-days			56 days		
				VSI-1	VSI-2	VSI-3	VSI-1	VSI-2	VSI-3	VSI-1	VSI-2	VSI-3	VSI-1	VSI-2	VSI-3
SCC 400	NRS	280	120	22.0	20.0	23.0	30.5	28.5	31.5	43.0	41.2	45.0	51.4	49.4	51.4
	M-Sand	280	120	26.7	24.7	28.7	33.0	31.0	35.0	50.8	47.8	52.8	57.9	55.9	57.9
SCC 450	NRS	315	135	24.5	22.5	25.5	34.3	32.3	35.3	51.8	49.8	52.8	58.6	57.6	58.6
	M-Sand	315	135	28.0	26.0	30.0	38.0	36.0	40.0	55.0	53.2	57.0	60.2	59.2	60.2
SCC 500	NRS	350	150	28.9	26.9	29.9	38.0	37.0	39.0	58.0	57.0	59.0	64.8	63.8	64.8
	M-Sand	350	150	32.0	30.0	34.0	42.5	40.5	44.5	62.5	60.5	65.5	69.0	67.0	69.0
SCC 550	NRS	385	165	31.8	29.8	32.8	43.5	41.5	44.5	60.0	58.0	61.0	67.0	65.0	67.0
	M-Sand	385	165	35.7	33.7	31.7	46.0	43.0	48.0	69.0	67.0	72.0	77.0	75.0	77.0

Table 11 Comparative compressive strength (average) of VSI aggregates

	Mix Designation	3 days Compressive Strength expressed as % of 28 day strength		7 days Compressive Strength expressed as % of 28 day strength		56 days Compressive Strength expressed as % of 28 day strength	
		NRS	M sand	NRS	M sand	NRS	M sand
VSI aggregates	SCC400	51.2	52.6	70.9	65.0	120	114
	SCC450	47.3	50.9	66.2	69.1	113	109
	SCC500	49.8	51.2	65.5	68.0	112	110
	SCC550	53.0	51.7	72.5	66.7	112	112

Durability test: Water permeability test as per DIN 1048 [7] was conducted on cylindrical specimens of SCC to ascertain resistance to water penetration. Depth of penetration of water through the specimens is tabulated in Table 12.

Table 12 Depth of penetration of water through SCC specimens.

Mix Designation	SCC 400		SCC 450		SCC 500		SCC 550	
	NRS	M-Sand	NRS	M-Sand	NRS	M-Sand	NRS	M-Sand
	Depth of Penetration of water in millimeter (mm)							
VSI-1	5	4	4	3	3	2	2	2
VSI-2	6	6	4	4	4	2	2	2
VSI-3	5	4	4	3	3	2	2	2

DISCUSSION

1. Particle size distribution is determined for both NRS and M-sand by conducting sieve analysis. Both fine aggregates conformed to Zone-II requirements as per IS 383-1970 (Reaff. 2007) indicating a good quality and are found suitable for SCC.

2. Specific gravity of M-sand is in the range of 2.65 to 2.66 which are normal values for aggregates of granite origin. In case of NRS specific gravity is found to be 2.63.

3. Materials finer than 75µm is also called as silt content for NRS. Its value shall be less than 3%. In the present case it is only 1.8%. In case of M-sand the maximum limit is 15%. In all the three sources of M-sand used for investigations, materials finer than 75µm have values in the range of 9%-11%. Since M-sand production plants have washing facility, the microfines are reduced considerably.

4. Bulk density measurements are done both in loose and rodded condition for both NRS and M-sand. From the results of tests conducted on fine aggregates it is observed that bulk density of manufactured sand is higher than natural sand. This is due to the presence of more fines passing through 600µm 300µm, 150µm and 75µm IS sieves in comparison with natural sand . Bulk densities of all three M-sand from VSI crushers were found be in the same range. Water absorption of M-sand is slightly higher than NRS

5. Of the cementitious contents considered (400 kg/m3, 450 kg/m3, 500 kg/m3 and 550 kg/m3) in SCC mixes, slump flow increases as the cementitious content increases as more paste is available to initiate flow of SCC. However, when paste volume adopted is less than the minimum required, slump flow is always found to be less than 600 mm.

6. For all SCC trials the slump flow values obtained are in the range of 550 mm to 760 mm. This satisfies the requirement of slump flow classes SF1 and SF2 as per EFNARC-2005 [8]. Considering slump flow M-sand is found to perform better than NRS and VSI type aggregates are found to perform better than non-VSI aggregates.

7. For all SCC trials the V-funnel time in sec obtained is 5 seconds to 15 seconds. This satisfies the requirement of VF1 and VF2 as per EFNARC-2005

8. For all SCC trials the L-box ratio obtained is 0.75 to 1.0. This satisfies the requirements PA2 with three bars as per EFNARC-2005

9. The difference between normal slump flow and J-Ring slump flow was found to be less than 50 mm in all trials. This is an indication of acceptable passing ability of SCC mixes.

10. Compressive strength of SCC mixes made with M-sand is found to be greater than SCC mixes made with natural river sand. This is essentially due to particle packing effect of M-sand from VSI crushers.

11. Depth of water penetration during water permeability test is observed to be very low being in the range of 2 mm- 6 mm for SCC made with VSI aggregates along with M-sand. This is due to particle packing effect which results in dense concrete.

CONCLUSION

Based on the experimental investigations carried out on manufactured sand from vertical shaft impact crushers it can be concluded that properly proportioned SCC mixes performed better than natural river sand in all aspects pertaining to flow properties, compressive strength at all ages and durability in terms of water penetration. M-sand is an ideal choice for SCC because of the presence of more fines in comparison to river sand,

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Pond Ash and Construction Demolition Waste as Fine Aggregate

Dr. R. V. Ranganath

1. Introduction:

The increased construction activities throughout the world have lead to the use of naturally occurring materials indiscriminately and created a situation wherein sustainability has become a major threat. Engineers of today have great responsibility in building nations with appropriate use of technologies and materials that are available locally.

It is well known from classical concrete technology that aggregates are used as fillers to provide skeletal frame work to concrete. The choice of different size of aggregates comes from the point of achieving least voids in order to use minimal binder which is otherwise expensive. The bigger sizes (recognized as coarse aggregates, the size of which ranges from 40mm to 10mm) in concrete is intended to occupy most of the volume and the voids created by them are to be filled up by the smaller fractions (recognized as fine aggregates) of size normally accepted in the range of 5mm to 150microns throughout the world.

As we are aware any inorganic material to qualify as fine aggregate has to have some of the following characteristics:

- Inert in nature(chemically inactive)
- Available in a suitable size fractions to meet grading requirements
- Appropriate shape to enable particle packing and hence least voids
- Should not have any impurities (organic) in the available forms
- Available abundantly within a reasonable distance

The use of natural river sand as fine aggregate in cement mortar and concrete is historic and has evolved over a period of time due to its easy availability along the river beds as civilizations existed mostly along the river coasts. Natural sand satisfies all the above requirement of a fine aggregate and is available abundantly. However, with the changed environmental stipulations for sustainable growth to maintain the ground water table, various Govt. agencies have imposed ban on quarrying of sand along the river beds. This action of the Govt. has already created pressure on supply of sand to meet the demand of fast pace construction. Further increased demand for construction in any developing nation is only likely to increase the price of such fine aggregate which was once considered as filler to achieve economy. In view of the changed scenario, it is everyone’s responsibility to look for new alternative materials which satisfy the requirement of fine aggregate. The search for such materials has already begun and implemented in few countries. Ready to use plasters with industrial wastes and manufactured sand for concrete are the few examples. In view of the changed scenario, manufactured sand or M-sand or Robo-sand as it is known has emerged as a competitive alternative to natural sand throughout the world. And its use has been well documented. However, the energy needed for crushing to the required gradation and availability of stone quarries in the long run are the two concerns in terms of sustainability. Among other alternatives, Pond ash (thermal power plant waste) and Crushed Demolition Waste (CDW) appear to be potent alternatives to be explored.

2. Pond Ash as Fine Aggregate in Concrete:

More than 60% of India’s energy is met by thermal power plants spread across the length and depth of the country. Fly ash is the residue resulting from the combustion of pulverized coal in thermal power plants. Finely divided ash is collected by electrostatic precipitators (ESP). This fly ash is predominantly being used in production of blended cements very coarse particles of the ash that get collected at the bottom of the furnace along with un-burnt coal are termed as Bottom ash. Coarser and un-utilized fly ash along with bottom ash mixed together with water is let into large ponds by pumping. This ash deposited in pond is known as Pond ash or Lagoon ash. The current annual production of Fly ash in India is over 120 million tonnes and the utilization is just over 30%. Thus, it is desirable to explore the ways and means of utilizing this large deposition of pond ash which otherwise creates environmental problems.

Construction industry is one such field where there is abundant scope for utilizing the pond ash in large quantities. Characterization of such material will help in understanding the behavior of pond ash thereby paving ways for effective and large scale utilization. Characterization is the study to determine the physical and chemical properties of pond ash obtained from a given source.

Ranganath R V et al., [1-3] have reported characteristics of pond ash collected from Badarpur TPP near Delhi and its possible use as fine aggregate in concrete. They have shown that it is possible to use pond ash as fine aggregate in partial replacement of sand up to about 40%. Pond ash in its as collected state is finer (60% material finer than 600 micron sieve) and more or less represents zone 4 sand and hence reproportioning of coarse and fine aggregates is required in order to maintain the desired workability. However, they have not used any super plasticizers to enhance workability. The concrete using pond ash has been reported to of good strength and in fact enhanced durability due to some pozzolanic action of the reactive pond ash. The pond ash itself as a material has been reported to contain Silica, alumina and iron oxide as major compounds. It also contains unburnt carbon (Loss on Ignition) of about 4 to 6% which is well within the prescribed limits as IS 3812. Minerologincally, it has quartz, mullite and hematite as major constituents representing silica, alumina and iron oxide. Morphologically, it has both spherical particles with smooth texture on the surface indicating favourable reaction sites and sintered/agglomerated particles indicating coarser fractions which are likely to affect both workability and pozzolanic action.

Recently, Kalgal M R and Pranesh R N [4] have reported the use of pond ash collected from Raichur TPP in Karnataka as fine aggregate as partial replacement up to 40%. They have also reported similar findings as far as characteristics of pond ash are concerned namely, very fine in size physically (Table 1and Fig 1), silica, alumina and iron oxide as major chemical compounds (Table 2), quartz, mullite and hematite as mineral constituents(Fig.2) and spherical and irregular (sintered) particles morphologically(Fig 3). They used two design mix concrete of grades M30 and M60 and replaced the sand systematically up to 40%. They have reported that there is no loss of workability and strength when pond ash is used. Though the initial strengths are slightly lower, long term strengths compensates for the initial loss (Table 3-6). They have also reported the use of pond as fine aggregate as full replacement to sand with very encouraging results. It is estimated that more than 1000 million tonnes of Pond ash is lying in the ash ponds near thermal power plants and hence appears to be good source for use as fine aggregate up to about 150km radius. However, some more experimental and pilot studies are required to establish the use of pond ash as full replacement to sand. Construction industry should look at this material with some more optimism.

Table 1: Sieve analysis results of different Pond Ash samples

Sieve Size (mm)	% Passing			
	P1	P2	P3	P4
4.75	99.79	98.94	99.88	99.84
2.36	98.83	97.16	98.71	98.98
1.18	95.43	93.52	96.45	97.48
0.6	77.31	76.06	83.41	89.40
0.3	58.18	58.68	69.42	77.65
0.15	29.78	31.40	41.57	44.67
0.075	14.18	13.10	14.17	13.75
0.045	7.23	6.00	7.47	6.58

Table 2: Chemical Composition of different Pond ash samples

Sample	P1	P2	P3	P4
LOI (%)	2.61	4.63	2.06	4.55
Total Silica (%)	68.29	67.44	68.1	65.78
Alumina (Al_2O_3) (%)	18.66	18.64	18.90	21.56
Iron Oxide (Fe_2O_3) (%)	12.80	6.40	9.00	5.80
CaO (%)	3.00	3.20	2.20	2.40
MgO (%)	0.40	0.50	0.40	0.50
Sulphuric anhydride (SO_3) (%)	0.40	0.18	0.28	0.35
Soluble Salts (%)	0.16	0.18	0.15	0.19

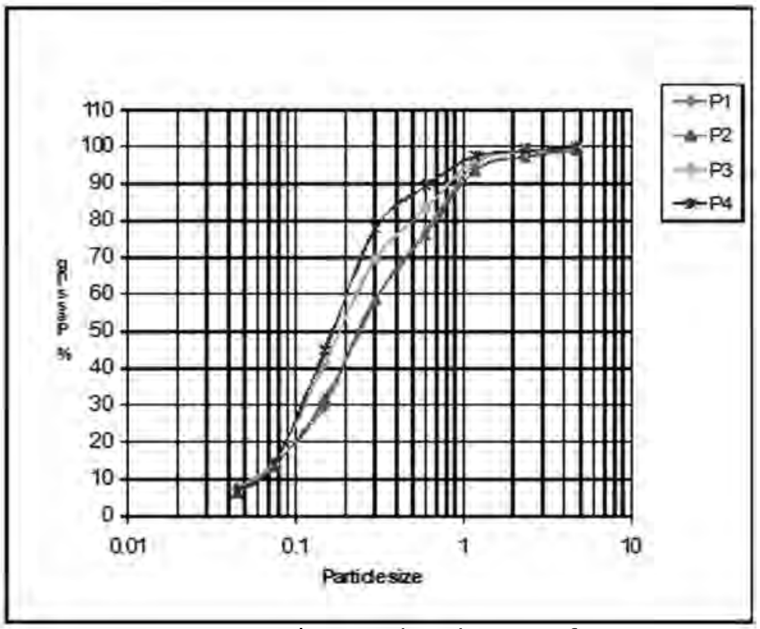

Fig 1: Particle size distribution of PA

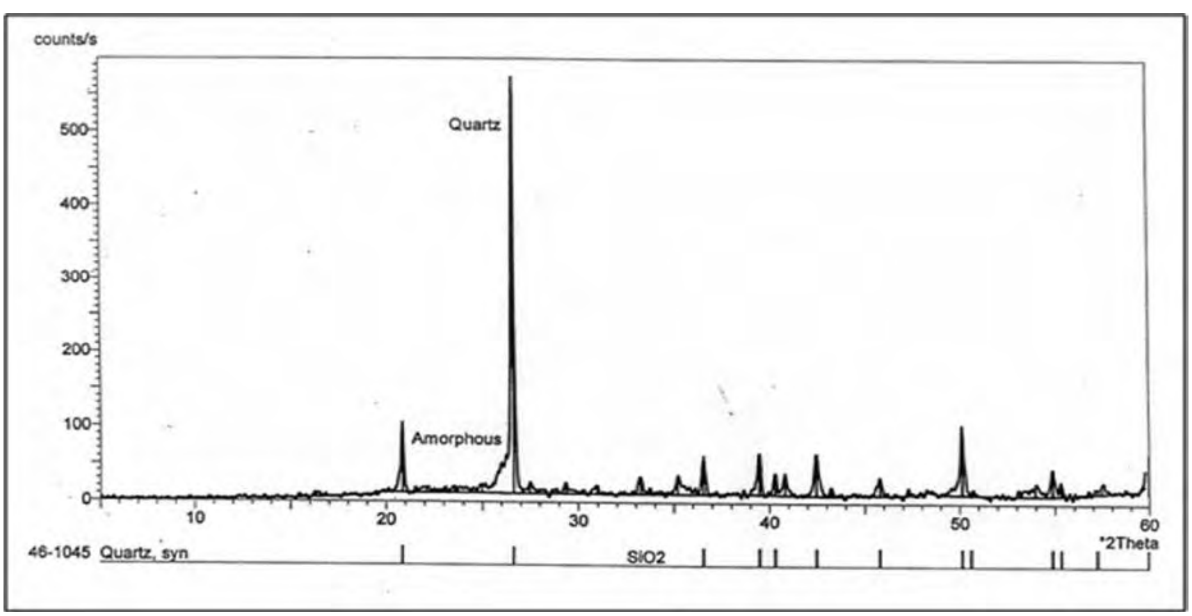

Fig 2. XRD image of PA sample

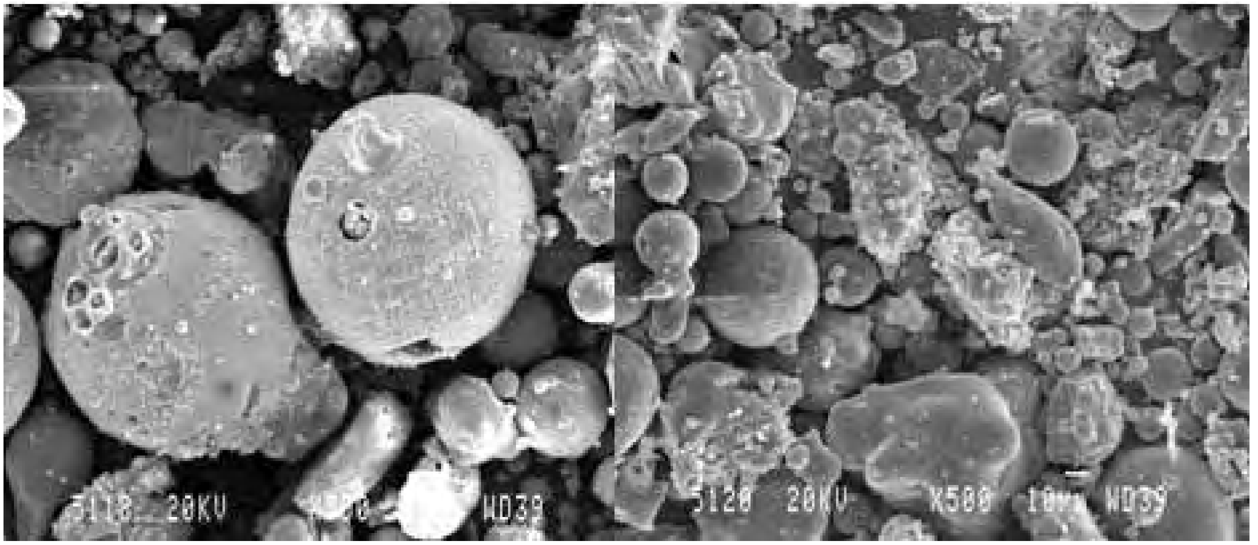

Fig 3. Scanning Electron Microscope image of PA sample.

Table 3. Mix proportioning for M 30 concrete

Mix	Batch Quantity Kg/Cum				
	Fine Aggregate	Pond ash	Coarse Aggregate	% CA in total aggregate	Compaction factor
CC3	825	0	1140	58	0.79
20PAC1	377	94	1494	76	0.82
30PAC1	330	142	1494	76	0.78
40PAC4	283	189	1494	76	0.78

M30 Grade Concrete, W/c = 0.56, Cement content = 330kg/m^3

Table 4. Mix proportioning for M 60 concrete

Mix	Batch Quantity Kg/Cum				
	Fine Aggregate	Pond ash	Coarse Aggregate	% CA in total aggregate	Compaction factor
CC3	764	0	972	56	0.85
20PAC1	333	83	1319	76	0.83
30PAC1	292	125	1319	76	0.83
40PAC4	250	167	1319	76	0.77

M60 Grade Concrete, W/c = 0.40, Cement content = 430 kg/m^3, SP=2.50%

Table 5. Compressive Strength of Concrete at different replacements.

Sample	7th Day Strength (Mpa)	%Change in strength	28th Day Strength (Mpa)	%Change in Strength	56days strength (Mpa)	%Change in Strength	90days strength (Mpa)	%Change in Strength	180days strength (Mpa)	%Change in Strength
Control Concrete	40.66	-	53.66	-	58.00	-	57.66	-	57.66	-
20% Pond Ash	34.66	14.75 (D)	49.66	7.45 (D)	51.33	11.50 (D)	55.00	4.61 (D)	55.66	3.47 (D)
30%Pond Ash	32.33	20.48 (D)	49.00	8.68 (D)	48.66	16.10 (D)	55.00	4.61 (D)	60.00	4.00 (I)
40%Pond Ash	34.00	16.37 (D)	44.66	16.77 (D)	47.67	17.81 (D)	52.33	9.24 (D)	58.66	1.73 (I)

Table 6. Compressive Strength of Concrete at different replacements.

Sample	7th Day Strength (Mpa)	%Change in strength	28th Day Strength (Mpa)	%Change in Strength	56days strength (Mpa)	%Change in Strength	90days strength (Mpa)	%Change in Strength	180days strength (Mpa)	%Change in Strength
Control Concrete	51.66	-	60.00	-	60.33	-	61.66	-	62.66	-
20% Pond Ash	42.00	18.69 (D)	51.33	14.45 (D)	54.66	9.39 (D)	54.00	12.42 (D)	59.33	5.34 (D)
30%Pond Ash	37.00	28.37 (D)	45.00	25.00 (D)	47.66	21.00 (D)	46.00	25.39 (D)	56.00	10.62 (D)
40%Pond Ash	43.33	16.12 (D)	52.66	12.23 (D)	41.66	30.94 (D)	55.66	9.73 (D)	54.33	13.29 (D)

3. Construction Demolition Waste as Fine Aggregate:

Recycling and reuse of waste such as building rubble, concrete lumps generated at construction and demolition sites form part of a wider, complex issue, primarily relating to improving supplies of construction material and solving problems of disposal of waste construction material. Estimates of demolished concrete in European countries and the US each year are close to 100 million tonnes. In these countries recycling of debris has already been started due to lack of disposal sites and strict anti-pollution laws. As per the survey conducted by the European Demolition Association [2], quite a large number of recycling plants are in operation in many European countries. A similar estimate of quantity of concrete discharged in Asia each year would also reveal a staggering figure. Although the problem in other parts of the world is not as alarming as in the West, it will not be long before these countries may also have to think seriously of reusing demolished concrete for the production of recycled concrete.

In India the demolition of many structures has already been started, producing huge quantities of rubble. The quantity of demolition waste generated in India has not been quantified properly. It is thought that presently the yearly rate of demolition of buildings and other structures in the major cities has reached 1 to 2 percent. This is mainly due to the following reasons:

- Demolition of structures due to various reasons such as for future development due to natural disasters.
- Tested specimens from test laboratories, waste concrete from ready-mix concrete plants and precasting units.

With an enormous increase in the quantity of disposable material like waste concrete rubble on one hand and a continuous shortage of dumping sites on the other, the waste disposal problem is assuming serious proportions. Present practice of disposing the concrete rubble in cities is to dump it in low-lying areas. Shortage of dumping sites has resulted in sharp increase in transport and disposal costs. Further, conservation of natural resources and preservation of good healthy environment is equally vital.

Most studies to date have been able to demonstrate that recycled aggregates can be used as a supplement to natural aggregates or under certain conditions instead of them. In any case, most results show that the properties of recycled aggregates as building materials are suboptimal compared to those of natural aggregates. Even concrete made with recycled aggregates from genuine crushed concrete from only one source simulating the situation prevailing in precast concrete plants was of lower quality than comparable concrete produced with natural aggregates.

Loss of quality in the material properties of recycled concrete has several reasons. The content of binder matrix in the recycled aggregate influences the material properties significantly. An increasing amount of cement in crushed concrete causes water absorption to increase and density to decrease. Other disturbing factors are the presence of impurities like wood or gypsum in the crushed concrete. These unfavourable characteristics are more noticeable in the fraction of crushed concrete fines. Therefore in most studies the fine fraction was replaced with natural sand. There are many studies which have mainly investigated coarse grained concrete obtained from demolition waste by dry recycling techniques. Since depending on the type of concrete and the type of crusher 20% to 50% of the crushed concrete is obtained as crushed concrete fines, it is obvious that recycling of crushed concrete fines is an important issue.

Current Status

World Scenario

In most countries, construction and demolition (C&D) waste goes towards land filling of low lying areas. Recycling and reuse of reclaimed asphalt pavement into new asphalt pavement aggregate, aggregate base and sub-base for roads and granular fill is now commonplace in the US. These are removed from the construction site or roadbed, crushed into aggregate and fines, and used in roadway and the shoulder base, shoulder surfacing and widening, driveway and parking lot maintenance, ditch linings, and pavement repairs. Concrete construction debris comes from the demolition of buildings, bridge supports, airport runways and concrete roadbeds and is broken up and crushed into fill, coarse and fine aggregate and base material for roads. Recycled aggregate from reclaimed asphalt pavement (RAP) & Reclaimed Portland cement concrete (RPCC) competes in the construction market with natural aggregate. In certain cases federal and state highway contracts for new highway construction require the use of recycled materials.

Hong Kong generates about 14 million tonnes of C&D waste each year and faces almost a crisis on how to accommodate this 'surplus' material. Apart from putting more efforts in minimizing its generation and setting up of temporary fill banks, recycling is one of the most effective means to alleviate the growing problem. In Oman and neighboring countries, RAP is becoming economically attractive because of aggregate shortage in certain regions and because of major road rehabilitation. C&D waste accounts for about 44% of the land fill in Scotland wherein, the majority of bituminous pavement demolitions and breakouts are recycled in low utility applications such as use in base course or sub-base course of roads. A significant proportion is recycled in intermediate utility applications such as railway ballast applications and only a relatively small amount in high utility applications such as reuse in surface wearing courses. Taiwan now recycles about 30% of road base material as RAP.

In Japan, the target for the recycling ratio of demolished concrete in the year 2000 was set at 90% and the actual results for 1990, 1993 & 1995 were 48%, 67% & 65% respectively. In 2000 it reached 96% but almost entirely as a sub-base material for road pavement. Several trails are now underway to enhance the use of demolished concrete for fresh concrete. In the European Union, the C&D waste generation is estimated to be at about 180-370 million tonnes which is approximately equivalent to 1 tonne per capita per year. Most of the European countries have targets for recycling ranging from 50% to 90% of the C&D waste production by the year 2010, as studies have indicated that recycled materials are generally less expensive than natural materials.

In Australia over 3 million tonnes of waste rubble largely concrete are produced annually. Approximately 50% of the material is recycled as Recycled Concrete Aggregate (RCA) and the remainder is sent to landfills. The Industry Commission Report indicated that 11% to 15% of the total waste sent to landfills in some major Australian cities was rubble from buildings. This figure has decreased in recent years due to increased recycling of building rubble. It was estimated that only approximately 200,000 tonnes of demolished concrete was recycled (to produce RCA) annually in Australia upto 1994. This figure has significantly increased in recent years approaching 1 million tonnes in the State of Victoria and more than million tonnes in New South Wales. Only a proportion of the recycled concrete however forms relatively good quality aggregate, the remainder is of lower grade.

In Australia, limited research has been conducted on RCA, and only a few references are available in the literature. Preliminary results on the use of RCA as a concrete making material have been encouraging. RCA was allowed to be used for road sub-base in the West Ring Road in Melbourne. This was a major breakthrough in the use of RCA in a large road construction project. It will be important to extend its use to the base course as which would need further research. RCA can be used in non-structural concrete of low sub grade. There seems to be a great need for investigating the suitability of the material for use in higher strength high performance structural concrete to increase its concrete construction.

The following table lists the annual production of construction and demolition waste in the European Union alone and its usage after recycling.

Recycling of Construction & Demolition Waste

Country	Annual Production (Million Tonnes)	% age used	Application of the %age used	
Belgium	70 (1990)	87%	Aggregate for concrete: 17%	Roads: 70%
France	24 (1990)	15%	Aggregate for concrete: 1.5%	Roads: 8.2%
				Embankments & fill: 5.3%
Great Britain	30 (1999)	45%	Aggregate for concrete: 2%	Roads: 9%
				Embankments & fill: 34%

European Union	18 (1999)	28%	Aggregate for concrete: 2.2%	Roads: 9.5%
				Embankments & fill: 16.3%
Spain	38 (2003)	10%	Sub base for roads: 3% As soil base: 3.5%; fill:3.5%	

(Source: Concrete International)

Indian Scenario

In India, the waste from construction industry is estimated to be about 12 to 14.7 million tonnes per annum.

The Central Pollution Control Board (CPCB) estimates current quantum of solid waste generation in India to be to the tune of 48 million tonnes per year, out of which the waste from construction industry accounts for about 12 to 14.7 million tonnes. Management of such high quantum of waste puts enormous pressure on the solid waste management system. At present, the management of waste from construction industry in India comprises of following elements:

- Reuse of only the selected materials salvaged in good condition during demolition.
- Sending metallic items for recycling through scrap dealers
- Dumping of the remaining items to low lying sites and dumping areas.

Estimated waste generation during construction and renovation/repair work is 40 - 60 kg/sq.m and 40 –50kg/sq.m respectively. The highest contribution to waste generation is from demolition of buildings which yields 500 and 300 kg/sq.m of waste, for pucca and semi-pucca buildings respectively.

Some experimental studies[5] conducted to ascertain the suitability of CDW fines as fine aggregate for functional mortars have shown very encouraging results and readily qualify for all the required grade of mortars as per IS standard (IS: 1905 -1981). Though the performance of mortar made with CDW is less than that of mortar made with sand, it performs better than mortar made with stone dust. Construction industry should look more closely to explore the possibility of using CDW as fine aggregate in functional mortar in packed form and ready to use.

Concluding Remarks:

Availability of natural sand as fine aggregate in cement mortar and concrete is likely to be scarce with the increasing stringent environmental enforcements. Engineers of today have great responsibility to maintain the growth of construction with sustainability. Alternative to natural sand are inevitable. Manufactured sand has emerged as the most competitive alternative and is being used in many construction projects throughout the world including India. In addition, construction industry should also look at Pond ash as fine aggregate in concrete and construction demolition waste as fine aggregate in functional mortars in ready to use forms.

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Use of Granulated BF Slag in Concrete

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1. Introduction

Aggregates typically occupy 70 to 80 percent of concrete by volume and are often viewed as inert filler that results in good physical properties at low cost. Naturally derived aggregates consist of natural sand and gravel, crushed rock, or mixtures of the two. Sources of high-quality aggregate near urban areas that are suitable for use in concrete are becoming increasingly more difficult to obtain as existing pits and quarries become exhausted. Part of the problem is that easily obtained sources of high-quality aggregates have already been exploited and difficulties in obtaining permits and local opposition often delay or block the opening of new gravel pits and quarries in urban and suburban locations. To reduce the burden on the environment, alternative materials to be used as fine aggregates are being extensively investigated all over the world. Looking to the quantum of requirements, quality and properties there has been a global consensus on a material - Granulated Slags. Granulated slag has been proven as a suitable material for replacing natural sand / crushed fine aggregates. In developed countries, the use of granulated slag as fine aggregate to replace natural sand is well established and is in regular practice. In the present paper granulated BF slag have been experimented for usage in concrete.

Slags are the main by-products generated during iron and steel production in the steel industry. Over the past decades, the steel production has increased and, consequently, the higher volumes of by-products and residues generated which have driven to the reuse of these materials in an increasingly efficient way. Slags are generated at two different stages of steel production, Iron making and Steel making known as BF slag and Steel Slag respectively. These slags are in liquid state and solidified in air after dumping in the pit or granulated by impinging water stream. BF slag is formed in the reduction process from iron ore,

coke, limestone etc. at temperature range from 1450 to 1550°C, thus contains lower iron oxides and is tapped off from time to time. The chemical compositions of the slag depend on the feeding raw materials and, smelting operation. The slag amount depends very much on the charging material, for example, the grade of iron ore. It varies from about 200 to 600 kg for producing one ton of hot metal. On average, it contains about 0.5–0.8 % FeO, 35–42% CaO, 35–40% SiO_2, 8–9% MgO, 8–15% Al_2O_3, 0.3–1.0% MnO and 0.7–1.5%S in weight. The slag basicity CaO/SiO_2 is in the range of 0.95–1.25. The slag processing techniques have made remarkable progress since 1970s in order to meet the different specifications and applications. The BF slags are usually solidified in four different ways: solidification in slag pots or pouring pads in air forms air-cooled slag; water quenching forms granulated slag; foaming with water structures pumice slag with high porosity; blowing with air or steam forms slag wool for thermal insulation. Due to the similar chemical compositions of the slag to that of the cement, the fast-cooled BF slag can be used as a high-value alternative to conventional Portland cement in a wide range of applications. The vitreous solidification of the BF slags in silicate glass forms is the essential condition for their hydraulic properties, which is affected by all the elements in the slag and cooling rate. Crushed BF slag for use as aggregate, ballast and lightweight building material has been an important industry for many years. Most of the modern steel plants now completely granulate the BF slag and use in cement making. However this granulated BF slag is very similar to natural sand and can be used directly as its replacement in construction. The present paper shows the use of granulated BF slag and crusher dust in concrete.

2. Granulated BF Slag

At JSW steel, BF slag is subjected to granulation through an innovative quenching technology. The process of slag granulation involves pouring the molten slag through a high pressure water spray in a granulation head, located in close proximity to the blast furnace. Granulation process is the controlled quenching of the slag in cold water which does not give time for crystalline growth to take place. During this process of quenching, the molten slag undergoes accelerated cooling under controlled water flow condition and gets converted into glassy sand with 97 % of the solid granulated slag particles less than 4 mm.

Fig 1: BF Slag Granulation

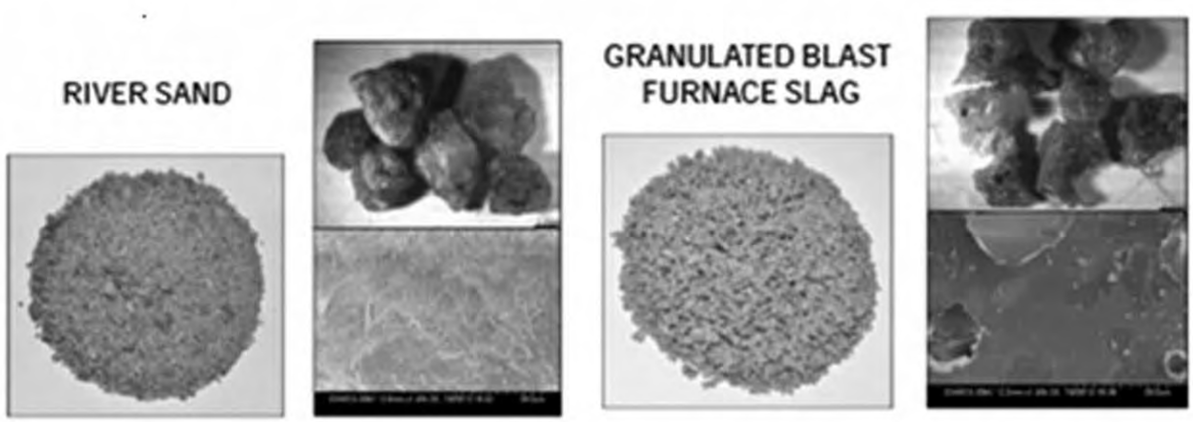

Fig 2: Comparison of river sand with granulated BF slag

Shape of the granulated slag sand is similar to river sand. Microscopically river sand and manufactured slag sand are also similar as shown in Figure 2. The granulated slag is screened to different size fractions based on application and requirement and is shown in the Figure 3. This wide distribution of size is required in aggregates used in construction. Due to its similarity to river sand this is seen as a potential material for replacing river sand in construction. However, to meet the requirement of specified fine aggregates, detailed characterization and laboratory tests are required. The present paper highlights the granulated BF slag characteristics and its usage in concrete.

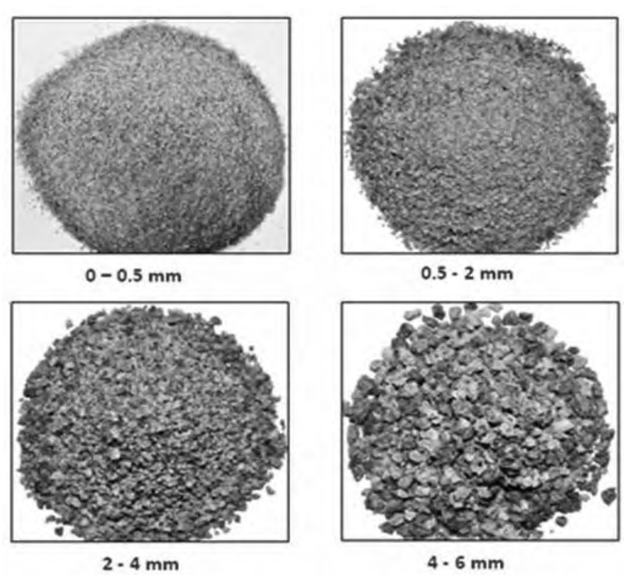

Fig 3: Screened granulated BF slag

3. Characterization of Granulated BF Slag

The visual observation of, as received samples of GBFS series indicated the color of the material was grey with a size distribution similar to sand and having angular edges. The details of the physical test of the BF slag are as below.

Table 1: Sieve Analysis of GBFS

IS Sieve Designation	Cumulative Percent		Specification as per IS:383-1970 (Reaffirmed 2007) for Fine Aggregate (Percentage Passing)			
	Retained	Passing	Zone-I	Zone II	Zone-III	Zone IV
10.00 mm	0	100	100	100	100	100
04.75 mm	0.5	99.5	90-100	90-100	90-100	95-100
02.36 mm	5.2	94.8	60-95	75-100	85-100	95-100
01.18 mm	42.5	57.5	30-70	55-90	75-100	90-100
600 microns	75.6	24.4	15-34	35-59	60-79	80-100
300 microns	93.7	6.3	5-20	8-30	12-40	15-50
150 microns	99.8	0.2	0-10	0-10	0-10	0-15
REMARKS: The tested sample satisfies the requirements of grading Zone I as per IS:383-1970 (RA in 2007).						

Table 2: Physical Properties of GBFS

Test Conducted	Results	Requirements as per IS:383-1970 (RA 2007)
Material finer than 75 microns (%)	0.6	Max. 3% by weight
Specific gravity	2.29	--
Moisture content (%)	7.7	--
Water absorption (%)	6.2	--
Bulking (%)	23.4	--
Bulk Density (kg/lit)		
Loose	0.978	---
Rodded	1.152	---

Table 1 and Table 2 confirm that the GBFS matches the requirement physical properties of fine aggregate to be used in concrete. The details of the chemical test of the BF slag are as below.

Table 3: Chemical Analysis of GBFS

Test Conducted	Results	Requirements as per IS:383-1970 (RA 2007)
Organic Impurities	Intensity of the colour developed by the test specimen is lighter than the standard solution indicating the presence of insufficient quantity of harmful organic compounds.	The aggregate shall not contain harmful organic impurities in sufficient quantities to effect adversely the strength or durability of concrete.
Light weight pieces	0.26	Max. 1% by weight
Soundness (%) (weight loss after 5 cycles)		
Sodium Sulphate	1.70	Max. 10%
Magnesium Sulphate	2.08	Max. 15%
Chloride (%), as Cl	0.0020	---
Sulphate (%), as SO3	0.020	---
pH	9.18	---
REMARKS: The tested sample satisfies the requirements as per IS:383-1970 (RA in 2007).		

Table 4: Reactivity Analysis of GBFS

Test Conducted	Results	Remarks
Alkali aggregate Reactivity: (millimoles/ltr). a) Reduction in Alkalinity of 1.0 N NaOH b) Silica Dissolved	 30.00 6.66	As per IS:2386 (Part VII) 1963 (Reaffirmed - 2002) the samples fall under innocuous aggregate i.e., the samples do not indicate potential deleterious degree of Alkali Reactivity

Table 3 and Table 4 confirm that the GBFS has no adverse chemical properties and are within the norms of fine aggregate to be used in concrete.

4. Experimentation

Granulated blast furnace slag has been experimented as replacement of sand (fine aggregate) in concrete with the use of OPC, PPC and PSC. Concrete mix designs were made as per IS-456. Compressive strength was determined by testing the 28 day cured cube specimen. The mean compressive strength values of 3 cube specimens are reported in the Tables below. The slag was also experimented in combination with crusher dust.

Table 5: M25 grade concrete with OPC using GBFS as fine aggregate

Mix Constituents	For one cubic meter of concrete (kg)	For 50 kg cement bag (kg)
Cement	340	50
Free Water	170	25
Fine Aggregate Granulated Blast Furnace Slag (GBS) 41.0%	769	113
Coarse Aggregate 20-10 mm (60%) < 10 mm (40%)	 661 441	 97 65
Chemical admixture MYK SAVEMIX SP 111 (MYK Schemborg) 0.8% by weight of Cement	2.72	0.400
Free Water Cement Ratio	0.5	
Workability in mm after one hour retention (Slump cone method)	100	
3 day Average Compressive strength (N/mm²)	13.04	
7 day Average Compressive strength (N/mm²)	17.63	
28 day Average Compressive strength (N/mm²)	32.00	

From Table 5, it can be concluded that granulated BF slag can be used as fine aggregate in concrete using OPC.

Table 6: M25 grade concrete with PPC using GBFS as fine aggregate

Mix Constituents	For one cubic meter of concrete (kg)	For 50 kg cement bag (kg)
PPC	340	50
Free Water	170	25
Fine Aggregate Granulated Blast Furnace Slag (GBS) 38%	709	104
Coarse Aggregate 20-10 mm (60%) < 10 mm (40%)	 691 461	 102 68
Chemical admixture MYK SAVEMIX SP 111 (MYK Schemborg) 1.0% by weight of Cement	3.40	0.500
Free Water Cement Ratio	0.5	
Workability in mm after one hour retention (Slump cone method)	120	
3 day Average Compressive strength (N/mm²)	16.44	
7 day Average Compressive strength (N/mm²)	22.81	
28 day Average Compressive strength (N/mm²)	33.21	

From Table 6, it can be concluded that granulated BF slag can be used as fine aggregate in concrete also using PPC.

Granulated BF slag was experimented using PSC in combination with crusher dust for various grades of concrete (M25, M30 and M40). Crusher dust is not considered as a good fine aggregate material. However in combination with granulated BF slag, it was found to have acceptable 28 day strength as shown in the below Tables. Performance of M25 and M30 grade concrete has been shown in combination with sand and crusher dust. The combined sieve analysis is shown in Table 7.

Table 7: Combined sieve analysis when mixed in 50:50 ratios

Sieve Size	Cumulative % passing when NRS and GS are mixed in 50:50 ratio	Cumulative % passing when CSS and GS are mixed in 50:50 ratio	Requirements of Cumulative % passing for Zone II as per IS:383-1970 (RA 2007)
4.75 mm	98.8	99.7	90-100
2.36 mm	94.7	86.7	75-100
1.18 mm	80.4	69.5	55-90
600 microns	47.2	41.9	35-59
300 microns	12.6	16.5	8-30
150 microns	2.5	6.9	0-10

Table 8: M25 and M30 grade concrete with PSC using GBFS and sand as fine aggregate

SUGGESTED MIX (BY WEIGHT) FOR CONCRETE									
Cement used*	Mix Designation	Aggregate Max. size (mm)	Cement Content (kg/cu.m)	Free Water Cement ratio (max)	Suggested Mix Proportions C:NRS:GS:CA**	Dosage of Admixture per bag of cement (ml)+	Slump Obtained (mm)	Compressive strength (N/sq.mm) 7 days	28 days
JSW, PSC	M25	20	390	0.42	1 : 0.93 : 0.98 : 2.85	375	110	21.4	32.9
	M30	20	440	0.37	1 : 0.8) : 0.85 : 2.47	400	105	26.1	39.9

Table 9: M25 and M30 grade concrete with PSC using GBFS and crusher dust as fine aggregate

SUGGESTED MIX (BY WEIGHT) FOR CONCRETE									
Cement used*	Mix Designation	Aggregate Max. size (mm)	Cement Content (kg/cu.m)	Free Water Cement ratio (max)	Suggested Mix Proportions C:CSS:GS:CA**	Dosage of Admixture per bag of cement (ml)+	Slump Obtained (mm)	Compressive strength (N/sq.mm) 7 days	28 days
JSW, PSC	M25	20	390	0.42	1 : 0.95 : 0.98 : 2.85	375	115	21.6	32.2
	M30	20	440	0.37	1 : 0.82 : 0.85 : 2.47	400	105	26.5	39.1

Table 10 shows a unique combination of PSC, granulated slag and crusher dust which can be used in M-40 grade concrete.

Table 10: M40 grade concrete with PSC using GBFS and crusher dust as fine aggregate

Cement used	Mix Designation	Aggregate Max. size (mm)	Cement Content (Kg/cu.m)	Free Water Cement ratio (max)	Suggested Mix Proportions C:GS:CSS:CA**	Dosage of Admixture per bag of cement (ml)+	Slump Obtained (mm)	Compressive strength (N/sq.mm) 7 days	28 days
JSW, PSC	M40	20	490	0.35	1 : 0.67 : 0.70 : 2.13	300	50	30.9	49.7

** Cement : Granulated Slag : Crushed Stone Sand : Coarse Aggregate

JSW Steel is extensively utilizing the granulated slag in construction works as complete replacement of fine aggregate and in combination with crushed dust. Most of the concrete roads are made using mix of crusher dust and granulated slag or granulated slag alone as replacement of fine aggregate. JSW is also utilizing slag in making paver blocks and concrete blocks for block work.

Fig 4: Usage of granulated BF slag and crusher dust at JSW Vijayanagar works

5. Conclusions

Granulated BF slag provides an eco-friendly alternative to river sand. The performance of concrete samples prepared replacing natural sand by granulated BF slag indicated that it could be gainfully utilized up to 100 % as replacement of natural sand in concrete with OPC, PSC and PPC. Granulated BF slag can also be used in combination with crusher dust in concrete.

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Strength and Durability of Concrete with Pond Ash as Fine Aggregate

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INTRODUCTION:

Ash is the residue after combustion of coal in thermal power plants. Particle size of the ash varies from around one micron to around 600 microns. From this ash generated, very fine particles (fly ash) that are collected by electrostatic precipitators is being used in the manufacture of blended cements. Unused fly ash and bottom ash (residue collected at the bottom of the furnace) are mixed in slurry form and deposited in ponds and is known as Pond Ash. Extensive Study has been undertaken by the authors to explore the possibility of utilising this Pond Ash in the construction industry, especially in making of concrete. Pond ash sample was procured from Raichur Thermal Power Plant (R T P S) Raichur Karnataka. Characterisation of pond ash sample was carried out and results indicated that Pond ash sample can be tried as fine aggregate in concrete[3].

LITERATURE REVIEW:

Extensive literature survey has been carried out and it is found that almost all the researchers have concentrated on utilisation of Fly Ash. Although extensive work has been done on the utilisation of fly ash as a replacement to cement, [1,2,4,6,7] work on utilisation of pond ash is scarce [3,5,8,9].

RESEARCH SIGNIFICANCE:

At R T P S alone, nearly 1700 tonnes of Pond ash is produced every day. Effective utilisation of pond ash is very essential to reduce environmental problems due to accumulation of pond ash. If found suitable for construction industry, large scale utilisation of pond ash is possible and this will become a major contributing factor for reducing pollution due to pond ash. Also a precious natural resource, viz. sand is becoming scarce and quarrying of sand has been restricted in many states in India. This has led the authors to look for possibility of total replacement of sand by Pond Ash.

EXPERIMENTAL PROGRAMME:

Strength and durability studies have been carried out on concrete with pond ash as full replacement of sand (Probably for the first time in this part of the world). Studies are being carried out on partial replacement of sand by pond ash also.

Ordinary Portland Cement (43 grade) conforming to IS: 8112-1989 was used throughout the project work. The cement obtained was stored in airtight drums to minimize the weathering effect. Normal consistency value obtained was 30%. Similarly Initial and Final setting time was 120 and 240 minutes respectively. Specific gravity of cement was 3.15 and the value of soundness based on Le Chatelier's method was 0.5mm. The results of other tests on cement are shown in table Nos 1 and 2

Characterisation of Pond Ash sample was carried out to ascertain physical and chemical properties of Pond Ash used in the investigations. Lime reactivity of pond ash sample was 0.66, specific gravity 2.33 and its bulk density was 824 Kg/m3 and 990 Kg/m3 in loose state and compacted state respectively. Chemical Analysis results of Pond Ash sample are tabulated in Table 3. Sieve analysis results of Pond Ash Sample used in the study are given in Table 4.

Locally available crushed granite passing through 10mm & retaining on 4.75mm IS sieve was used as coarse aggregate. Physical properties of coarse aggregate obtained were Bulk Density- 1470 Kg/m^3, Specific Gravity – 2.67 and Fineness modulus- 6.04. Grading of combined aggregates is given in Table 5.

Three typical CA:FA ratios viz., 62:38, 65:35 and 68:32 were chosen for the study. These are designated as M-I, M-II and M-III respectively. Under each of these ratios, two mix proportions with cement content of 330kg/m3 and 345 kg/m3, designated as Type A and Type B respectively, were chosen (Ref. Table 6).

To verify that good particle packing is achieved, software called LISA was used. LISA is a software that calculates and displays the particle size distribution of a mixture of components and compares that with theoretical packing. The nearness and conformity to the theoretical curve indicates achievement of maximum possible packing. It was originally developed for designing self-flowing refractory castable compositions at Elkem Materials. LISA works on the Andreassen and Modified Andreassen theory. Particle size distributions of different building products, ceramics, concrete etc. are investigated by this tool and this package has been used to determine the extent of packing for the chosen three aggregate ratios.

To obtain medium workability of 8-9 seconds of Vee Bee time, different dosages of a Naphthalene based superplasticiser were tried and 4% superplasticiser was found to be suitable for the above requirement.

Cubes of dimension 100mm have been cast adopting weigh batching and hand mixing technique. Steel moulds were used for casting and table vibrator was adopted for compaction. Cubes were demoulded after 24 hours and placed in water tanks for curing for 28 days after which they were air dried.

Density and compressive strength studies have been conducted on the mixes M-I, M-II & M-III. Durability studies have been conducted on concrete with mix that gave comparatively good particle packing as per the results of LISA output, i.e., mix M-III (Figures1 to 6).

RESULTS AND DISCUSSION:

Density and compressive strength values (up to 90 days) of mix M-I, M-II & M-III have been obtained and these values are tabulated in Tables 7 & 8. Figures 7 to 11 give the behaviour of concrete. Following points were observed from tables and figures.

Density

1. The average density of concrete in both mix proportions ranges from 20 kN/m3 to 22 kN/m3, which is slightly lesser than the normal concrete density with sand as fine aggregate. This reduction in density is probably due to lesser specific gravity of pond ash.
2. The weight of saturated surface dry, 28 day old cubes of both the grades indicate that M-III has probably achieved better particle packing, and hence exhibits higher densities than the rest.
3. It is also observed that the density exhibited is marginally lesser for 56 and 90 days due to probable evaporation of moisture from the pores in the surface layers.

Compressive Strength

1. In both Type A and Type B mixes, highest 28 days compressive strength (viz. 24.67 N/mm^2 and 29.33 N/mm^2 respectively) was achieved for M-III mix, which is expected to have better particle packing, followed by M-I and M-II.
2. There has been significant increase in the compressive strength between 28 and 56 days in both types of concrete and strength gain continues (somewhat at a slower pace) between 56 and 90 days.
3. From tables 2, 3 and figures 3 to.5, it can be seen that M-III is superior in terms of achieving higher compressive strength compared to M-I and M-II at all ages.
4. In general it can be said that, pond ash can be used as total replacement of sand (with modifications for CA: FA ratio) and that it is possible to achieve strengths beyond M20 required for reinforced concrete construction.

Durability Studies

From the results of L I S A out put for M I , M II & M III and the strength results, it was observed that mix M III is likely to have better particle packing and hence M III samples were used for durability studies in both Type A and Type B mixes.

Durability studies were conducted on 100 mm cubes of both Type A and Type B mixes by immersing these cubes in 5 % solution of Magnesium Sulphate, 5 % solution of Sodium chloride and 2N Hydrochloric acid solution. Effect of immersion in these solutions on compressive strength and weight have been observed at 28, 90, 180 and 360 days and tabulated in Tables 9 and 10.

From these tables it can be seen that there is no loss of strength and on the contrary strength has increased in almost all the specimens and no loss in weight. This indicates that the immersion in different solutions, has no adverse effect on concrete made with pond ash as fine aggregate and this concrete will be able to withstand the aggressive environment satisfactorily.

CONCLUSION:

This is probably for the first time that total replacement of sand by pond ash in concrete has been tried.

From the results of tests conducted and discussions thereof, following broad conclusions can be drawn

1. Total replacement of sand by Pond Ash is feasible.
2. The average density of concrete in both grades ranges from 20 kN/m3 to 22 kN/m3, which is slightly lesser than the normal concrete.
3. The weight of saturated surface dry, 28 day cubes of both the grades indicate that a coarse aggregate fine aggregate ratio of 68:32 can produce good particle packing and as indicated by higher density than the rest.
4. From compressive strength results it can be said that, pond ash can be used as total replacement of sand (with modifications for CA: FA ratio) without compromising on strength. Further studies are being carried out on mechanical properties to confirm this point.
5. From the limited durability tests conducted, it can be inferred that this concrete is likely to withstand the aggressive environment satisfactorily.
6. Detailed study on Pond Ash Samples from different Thermal Power Plants is needed to ascertain its suitability.

ACKNOWLEDGEMENT:

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Chemicals	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	LOI	SO_3	R_2O_3	IR
Cement	20.6	4.02	4.00	4.0	0.80	3.76	2.54	8.02	1.52

Table 1: Chemical Analysis of cement sample

Sample	Percent of water by wt.	Compressive strength in MPa		
		3 day	7 day	28 day
Cement	10.50	24.56	34.85	45.00

Table 2 : Compressive strength of cement

LOI (%)	3.46
Total Silica (%)	67.40
Alumina (Al2O3) (%)	19.44
Iron Oxide (Fe2O3) (%)	8.5
CaO (%)	2.7
MgO (%)	0.45
Sulphuric anhydride(SO3) (%)	0.30
Insoluble Residue (%)	90.58
Soluble Salts (%)	0.17

Table 3. Chemical Composition of Pond Ash (Sample P1)

Sieve Size	% passing
4.75mm	99.43
2.36mm	98.48
1.18mm	95.58
600microns	82.48
300 microns	65.63
150 microns	35.86
75 microns	5

Table 4. Sieve analysis results of Pond Ash sample

Sieve Size	% passing for Combined Grading
20mm	100.00
10mm	84.75
4.75mm	41.91
2.36mm	39.08
1.18mm	37.06
600μ	31.68
300μ	25.24
150μ	13.89
75μ	1.90
45μ	0.00

Table 5: Combined grading of coarse aggregate and pond ash.

Concrete Mix	Mix Designation	Cement (kg/m^3)	Pond Ash (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (lt/m^3)	Super Plasticizer (lt/m^3)
Type A	M-I	330.00	638.98	1050.00	216.12	7.70
	M-II	330.00	591.10	1097.83	212.30	7.70
	M-III	330.00	540.47	1148.50	208.24	7.70
Type B	M-I	343.75	638.00	1041.10	216.04	8.02
	M-II	343.75	587.70	1091.45	212.02	8.02
	M-III	343.75	537.32	1141.82	208.00	8.02

Table 6: Ingredients for M-I, M-II and M-III of Type A and Type B Mixes.

Mix designation	No. of Days	Avg. Dry Wt. of cubes (gms)	Avg. Density of cubes (kN/m^3)	Avg. Compr. Strength (N/mm^2)
M-I	28	2173	21.73	21.00
	56	2100	21.00	28.00
	90	2088	20.88	28.00
M-II	28	2151	21.51	19.67
	56	2106	21.06	27.33
	90	2088	20.88	28.00
M-III	28	2236	22.36	24.67
	56	2152	21.52	32.00
	90	2174	21.74	38.00

Table 7. Density and Compressive strength test results of Type A Concrete

Mix designation	No. of Days	Avg. Dry Wt. of cubes (gms)	Avg. Density of cubes (kN/m^3)	Avg. Compr. Strength (N/mm^2)
M-I	28	2182	21.82	22.00
	56	2094	20.94	30.00
	90	2094	20.94	32.67
M-II	28	2187	21.87	24.00
	56	2070	20.70	29.00
	90	2083	20.83	33.67
M-III	28	2204	22.04	29.33
	56	2178	21.78	35.00
	90	2084	20.84	40.00

Table 8. Density and Compressive strength test results of Type B Concret

Immersion Solution	Age in days	Av. initial dry wt. of cubes (gms)	Average weight after immersion (gms)	Compressive strength (N/mm^2)
Mg SO_4	28	2191	2189	31.33
	90	2150	2155	35.66
	180	2161.33	2200	40.33
	360	2162.67	2164	36.00
NaCl	28	2207	2214	33.00
	90	2195	2207	36.33
	180	2185.33	2203.33	37.00
	360	2184.67	2189.33	40.67
HCl	28	2146	2166	31.00
	90	2144	2167	27.66
	180	2106.66	2142	32.00
	360	2132	2141.33	28.33

Table 9.Variation in Weight and Strength of Type A concrete cubes in different solutions

Immersion Solution	Age in days	Av. initial dry wt. of cubes (gms)	Average weight after immersion (gms)	Compressive strength (N/mm^2)
Mg SO_4	28	2217	2222	40.00
	90	2209	2220	43.00
	180	2201.33	2216	37.66
	360	2161.33	2165	33.00
NaCl	28	2184	2191	43.00
	90	2190	2202	35.33
	180	2193.33	2170	34.67
	360	2192	2194	39.33
HCl	28	2168	2182	37.00
	90	2172	2191	35.00
	180	2140	2175.33	32.00
	360	2158	2172	37.00

Table 10. Variation of Weight and Strength of Type B concrete cubes in different solutions

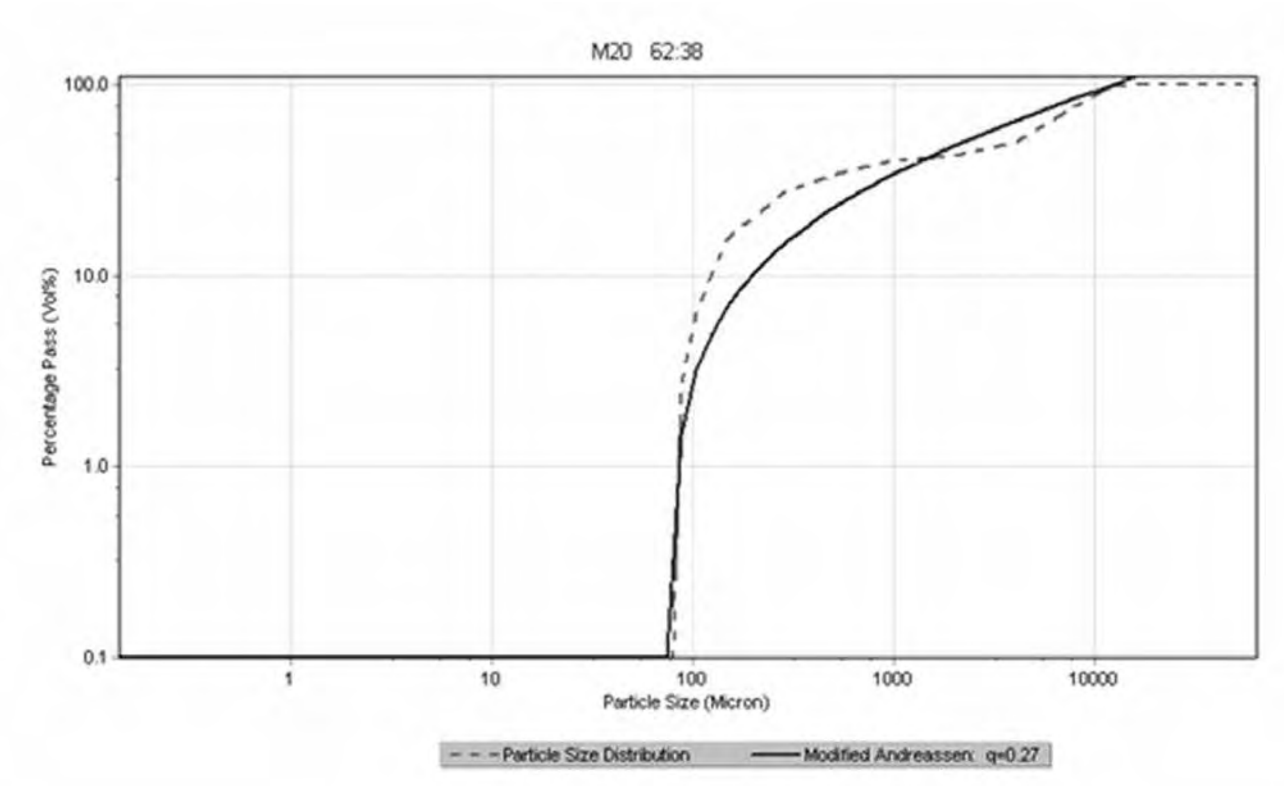

Figure 1. LISA output for M-I of M-20 grade concrete

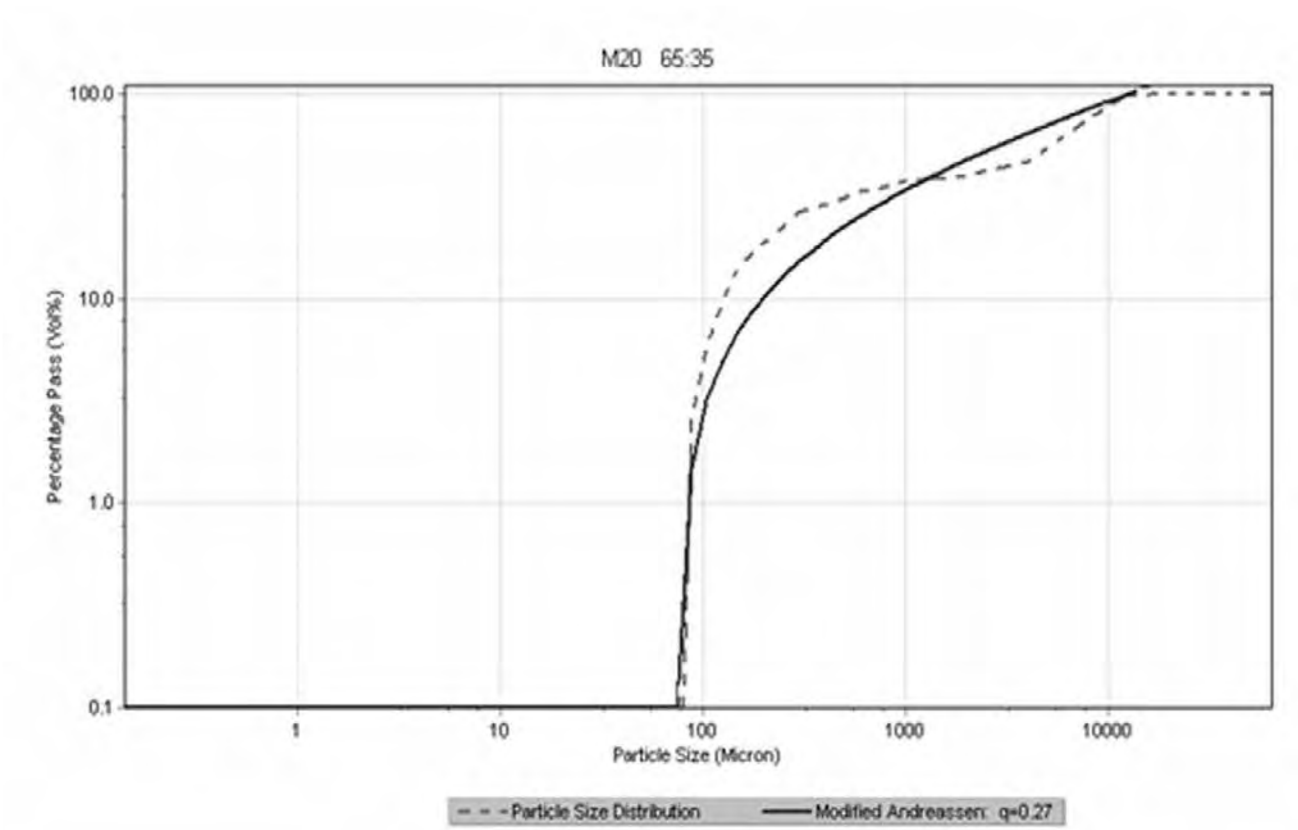

Figure 2. LISA output for M-II of M-20 grade concrete

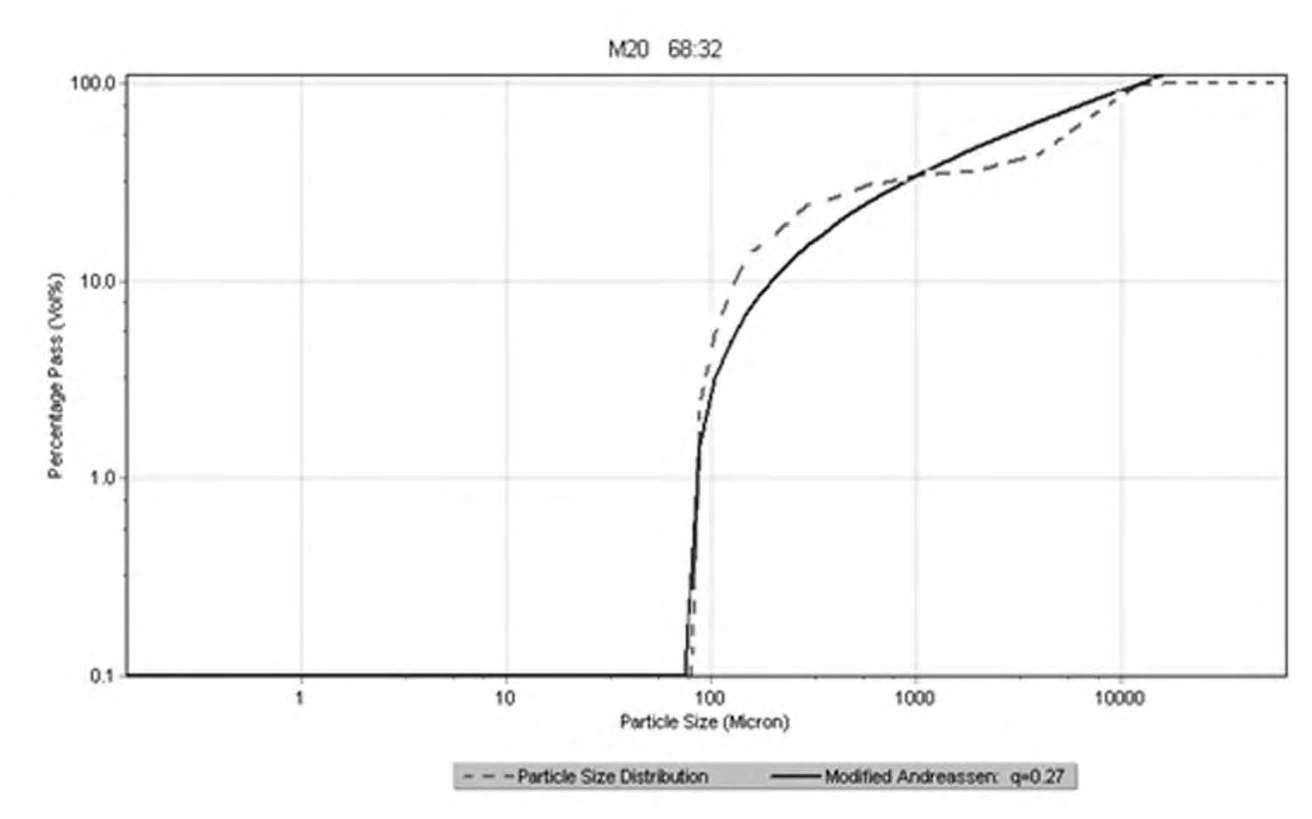

Figure 3. LISA output for M-III of M-20 grade concrete

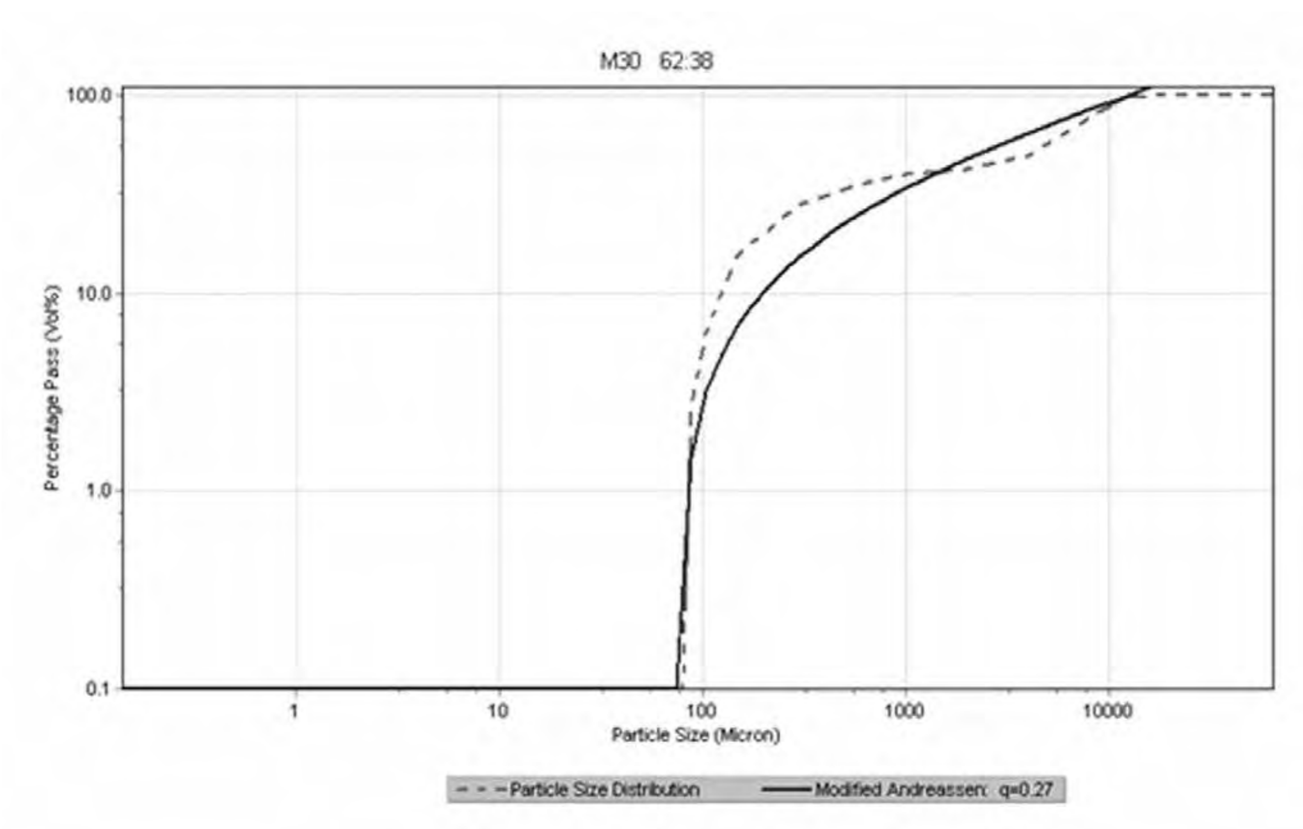

Figure 4. LISA output for M-I of M-30 grade concrete

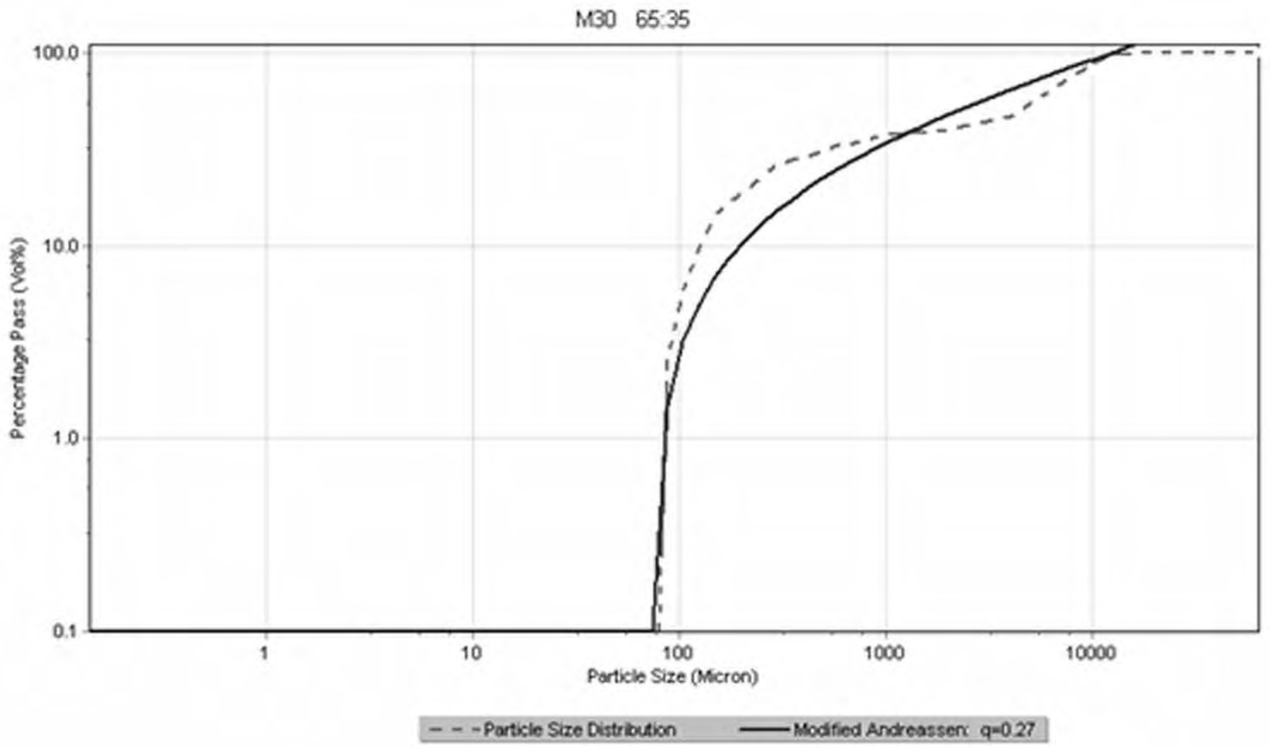

Figure 5. LISA output for M-II of M-30 grade concrete

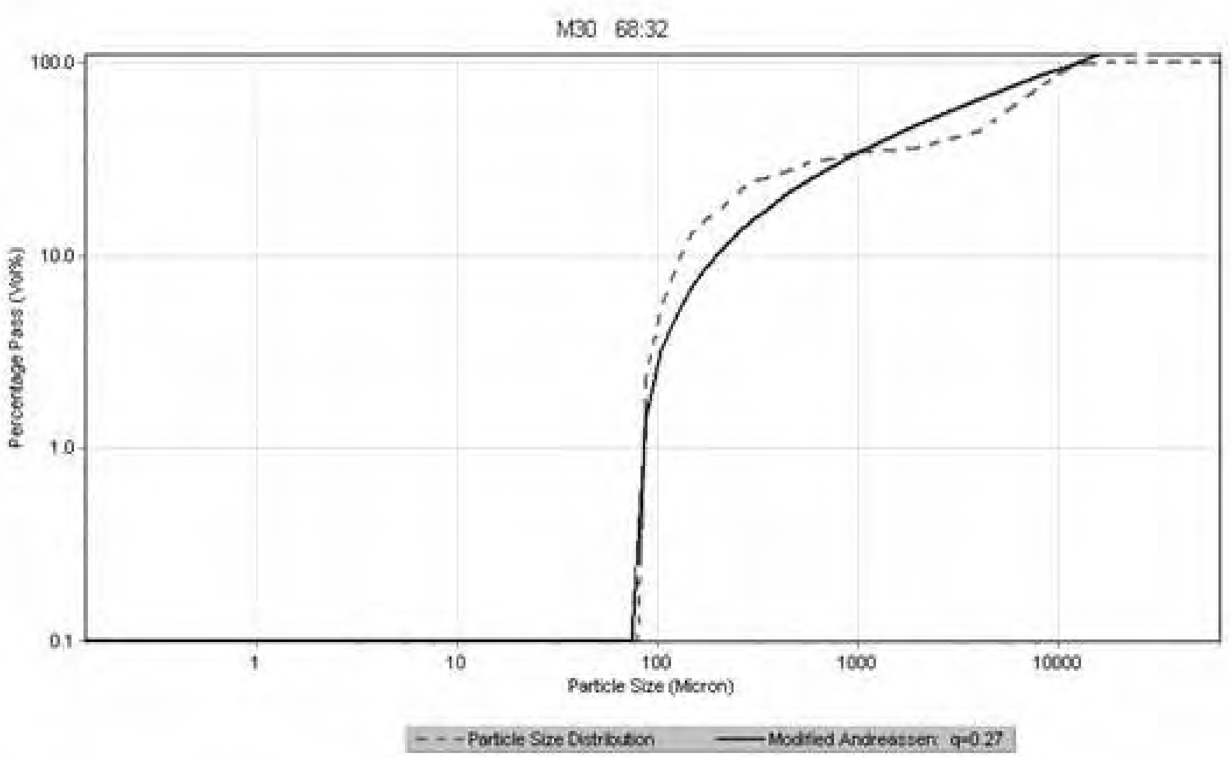

Figure 6. LISA output for M-III of M-30 grade concrete

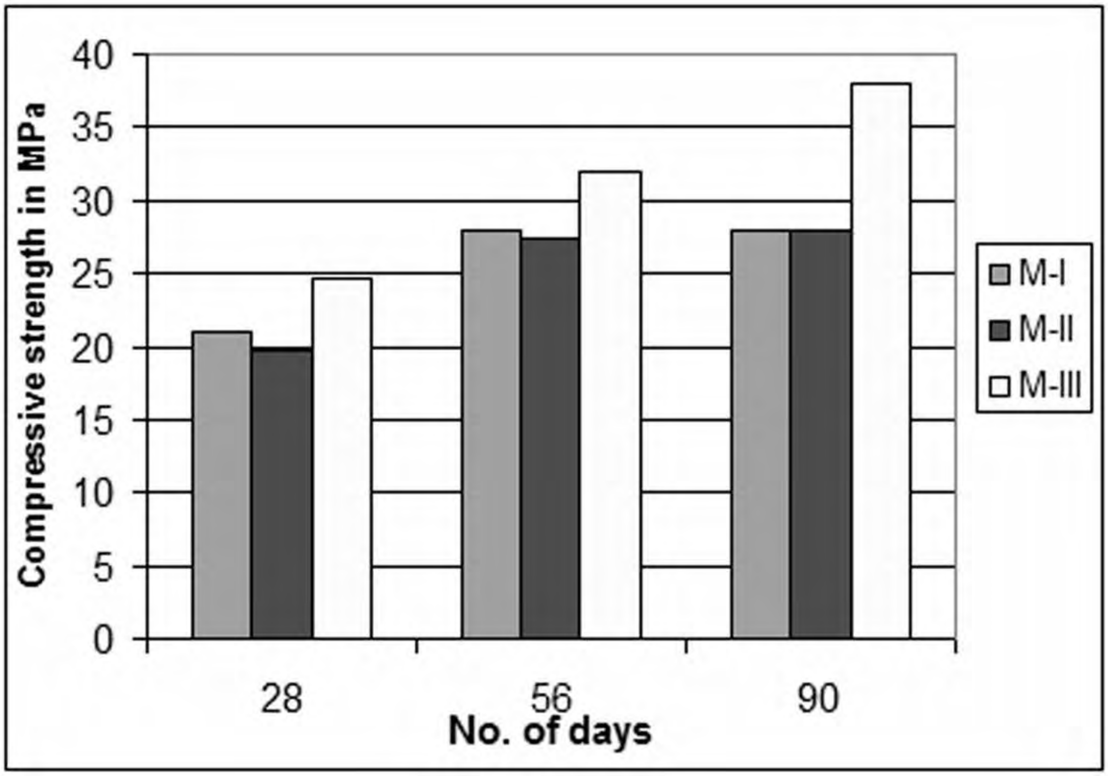

Figure 7. Comparison of Compressive strength for Type A concrete at different ages

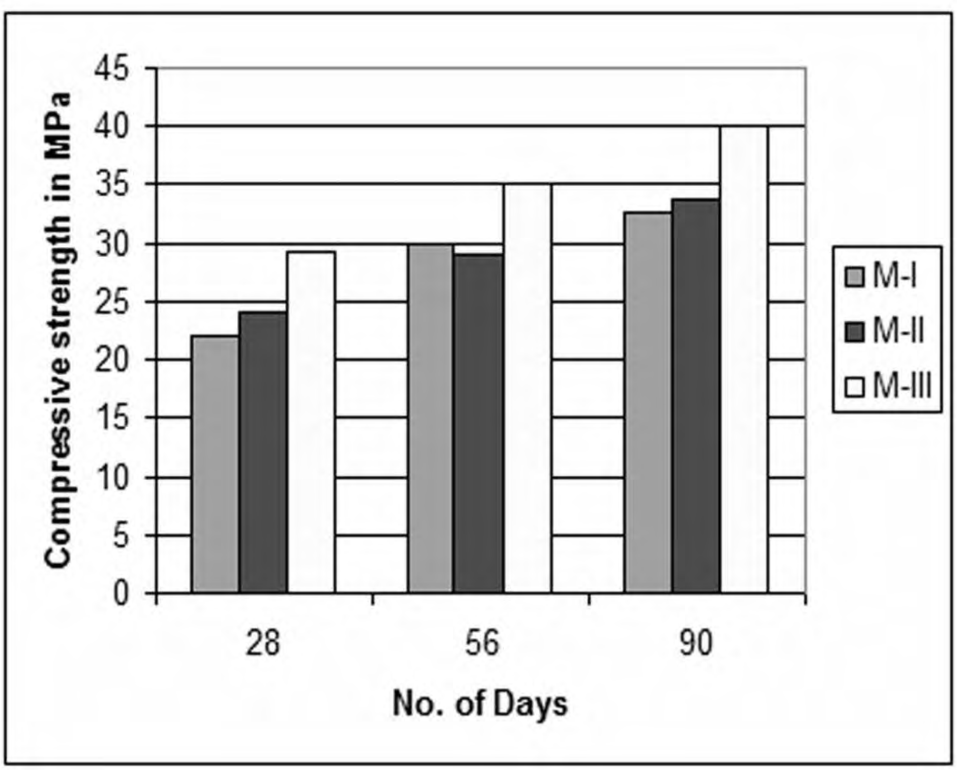

Figure 8. Comparison of Compressive strength for Type B concrete at different ages

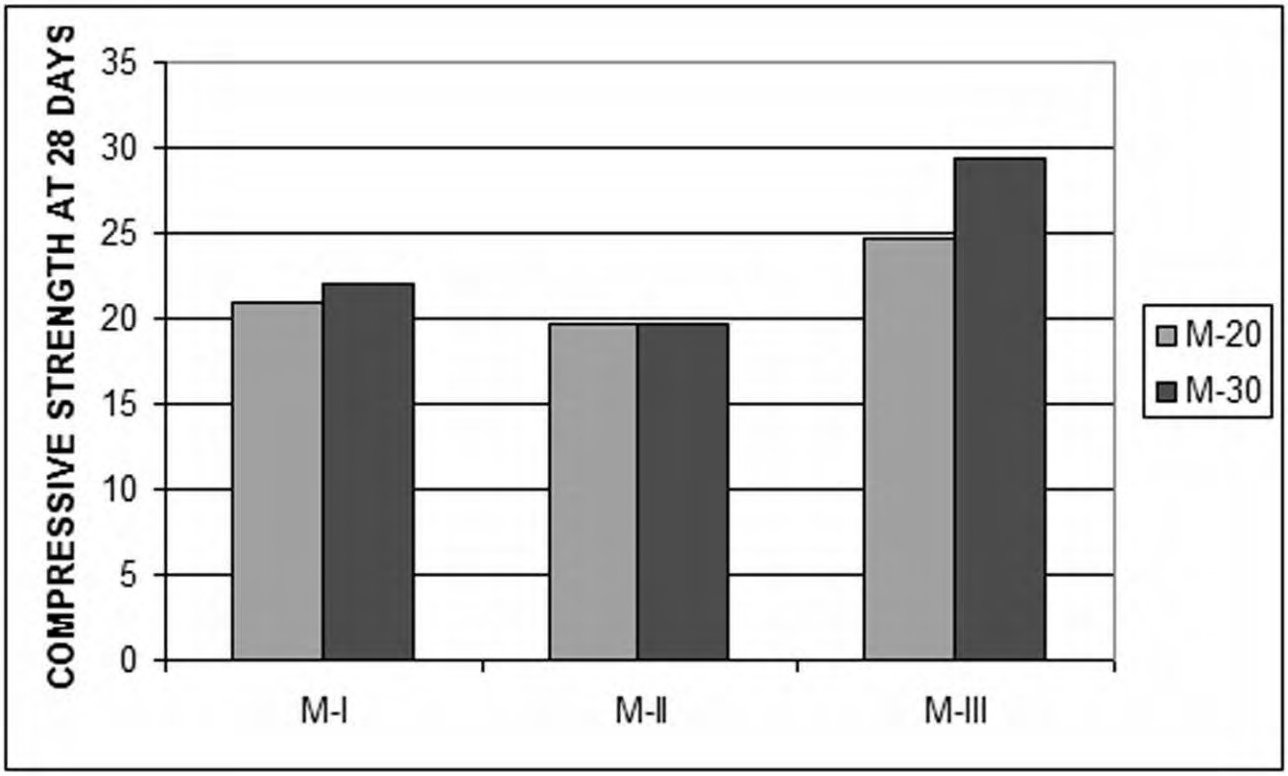

Figure 9. Comparison of compressive strengths at the end of 28 days

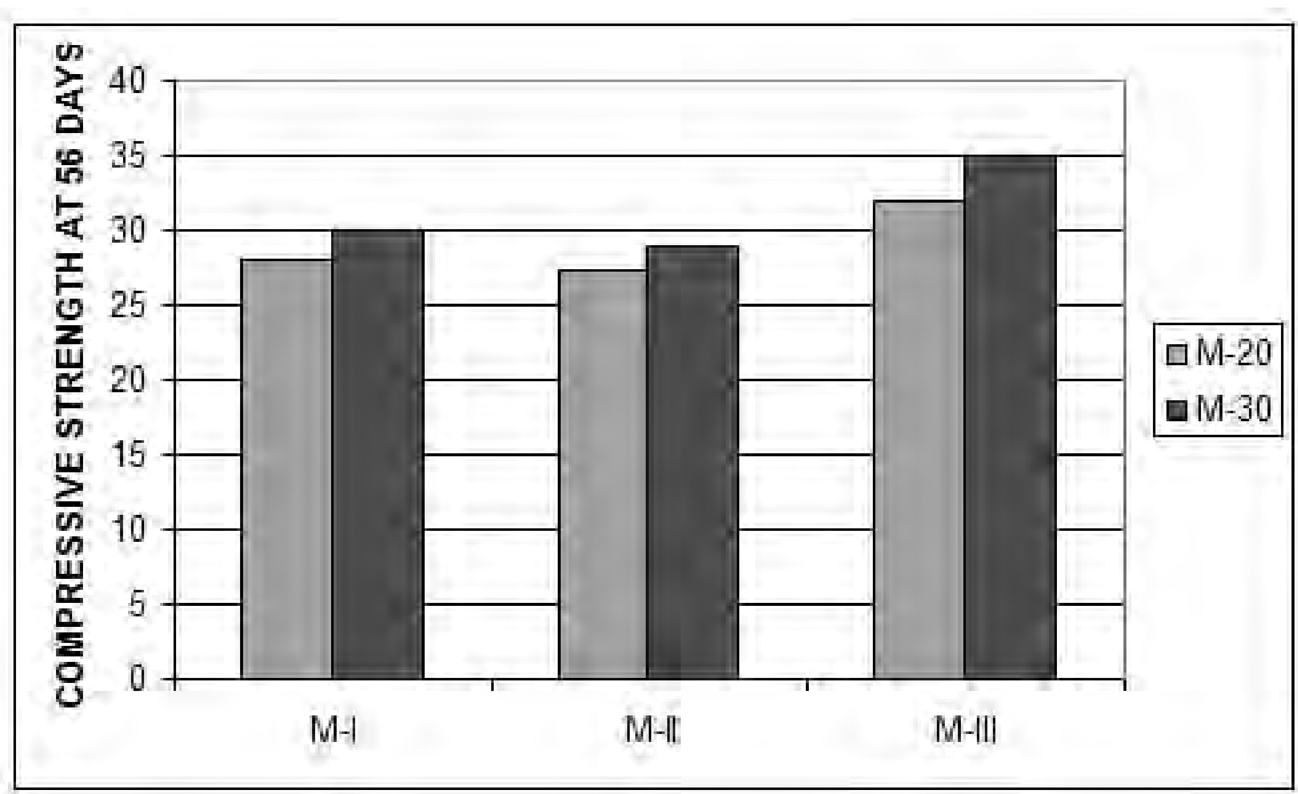

Figure 10 Comparison of compressive strengths at the end of 56 days

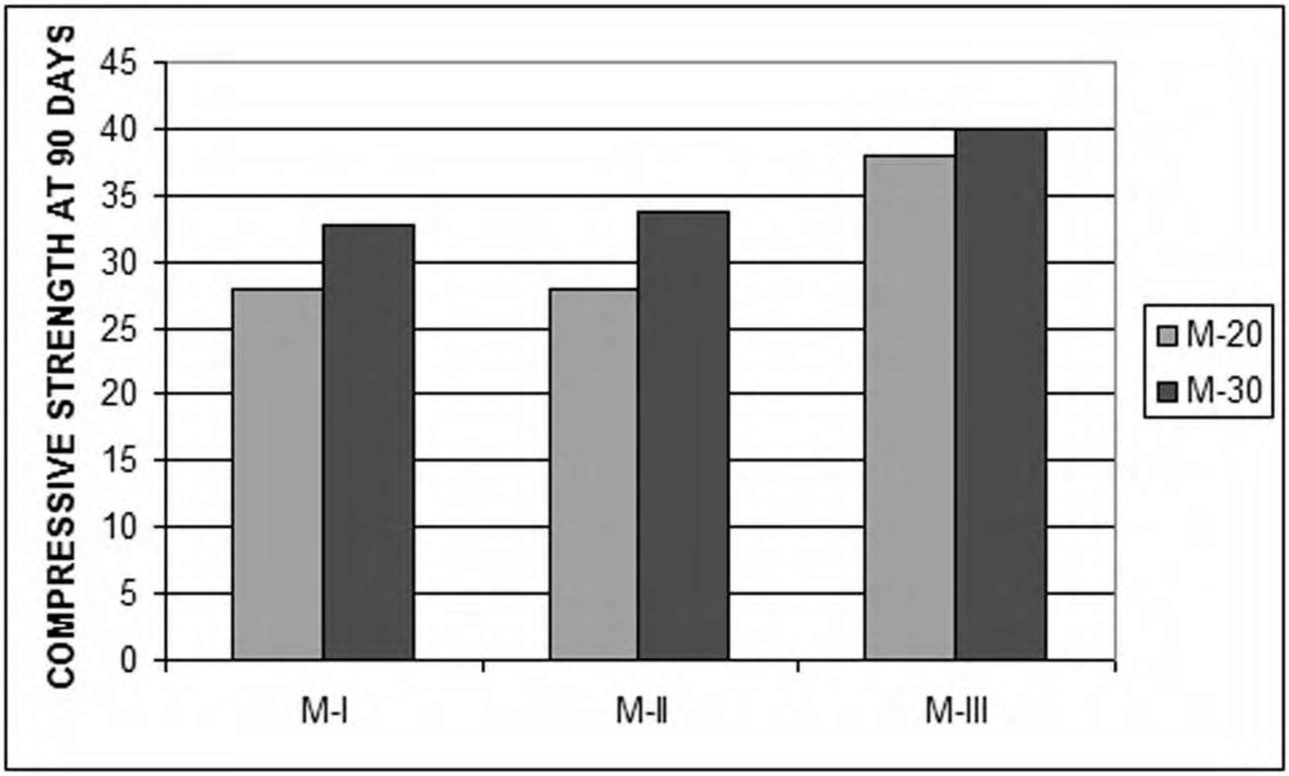

Figure 11 Comparison of compressive strengths at the end of 90 days

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Sand from Construction Demolition Wastes

Mohan Ramanathan

1. INTRODUCTION

Construction activities generate huge amount of construction and demolition (C&D) waste materials each year. The activities include site formation, tunneling works, demolition of building and structures, decoration and reconstruction works, new construction and maintenance works. Most of these materials are inert materials such as earth, rocks and concrete, which can be reused or recycled. Even timbers and wooden materials can be reused or recycled if properly handled. In the old days, when the materials were scare and expensive in comparison to labour costs, lots of these C&D materials had been salvaged and reused through balance cut and fill, rehabilitation, reclamation, reuse of brick and masonry, reuse of timber and wood to its maximum potential. With the prosperity and rapid development of a society, the society has become more and more extravagant and less concern on conservation of natural resources.

Factors contribute to this situation are.

a. Lower cost in quarrying of natural resources due to modern machines.

b. Low import cost of aggregates from neighbouring developing regions.

c. Demolition of buildings and structures long before the end of its designed or useful life.

d. Base "use and throw way" habit.

e. Tight development programme for quick financial return.

f. Improper or lack of waste management.

As a result, lots of natural resources were drained away as waste and required extra expense and resource to handle and accommodate. Worst still, it will not only create environmental and social problems, the society will consume the remaining natural resources at a much faster rate than is necessary. There is therefore a need for proper waste management for the sustainable development.

2. STRATEGY.

In order to minimize the adverse impact, both social and environmental, most developed countries have formulated their own strategies on management of waste at national level. Such measures include.

a. Mandating adoption of waste management plan at national level, such as in Germany, Denmark and Hong Kong.

b. Setting target on achievement on recycling by stages.

c. Imposing heavy tax on waste disposal.

d. Imposing aggregates tax to encourage use of recycled aggregates

e. Increasing effort in education and information on waste reduction and recycling to identify and exploit the opportunities of recycling and overcome the barriers and obstacles due to conservatism.

Generally speaking, the following strategy in hierarchical orders are adopted by most countries.

a. Minimizing the generation of waste in the first instance.

b. Reusing the C&D materials in its original from as far as possible.

c. Recycling with minimal input of energy.

d. Disposing of the waste environmentally, with waste to landfills.

3. WASTE MANAGEMENT PLAN

For successful implementation of the waste management strategy, it is required to formulate, implement, monitor and review of a Waste Management Plan during the whole life cycle of the projects. In advance countries, such as Germany and Denmark, Waste Management Plan has not only established at corporation level and project level, it has been extended to state level or even high to show the determination and commitment on waste management.

In general, the waste management plan should cover activities at all stages, from conceptual and planning stages, through design and construction stages, and to maintenance and reconstruction stages. Waste minimization, reuse, recycling and disposal should be well planned and implemented, monitored and reviewed at all stages, with life cycle cost on waste disposal taken into consideration.

In Hong Kong, the Government has issued technical circular requiring the implementation of waste management in public works projects. The Government is also encouraging the private sector to adopt the same. In addition, there is also drive to motivate financial incentive on management and reduction of waste by implementation of construction disposal charging scheme.

4. WASTE MINIMIZATION

Minimization of waste should commence at the onset of the project. This includes better planning layout, balanced cut and fill, use of precast construction, reuse and recycling of C&D materials on site with the minimal import and export. For redevelopment, rehabilitation of old building and structures should be considered during town planning to increase its useful life without the need for demolition. Demolition can also be avoided by redesignating disused or no longer functioned buildings and structures for appropriate usage. Adopting recyclable materials at the onset of the projects will cut down overall waste in the life cycle of the project. Further avoidance of waste can be done by proper procurement, handling and storing of construction materials on site during construction. In addition, adopting selective demolition and on-site sorting will maximize the potential for reuse and recycling and hence reduction in waste. Systematic and proper maintenance can slow down deterioration and prolong the useful life of building and structures to delay the process needed for reconstruction.

5. REUSE

In the old days, people had every endeavour to make the best use materials available and had every incentive to maximize the use of natural resources. In underdeveloped countries, people treat every piece of masonry, brick or tile, rock and crushed concrete as valuable. During the demolition, they will take down the bricks and good tiles carefully. striping out the mortar and properly stacked aside for reuse later. Even in advance countries, wooden doors can be carefully salvaged by adopting selection demolition, with the salvaged doors for reuse or resale in the 2nd hand market or 3rd or 4th world markets. Wooden planks or timbers can also be trimmed to size for appropriate reuse. Topsoil can be saved for gardening or landscaping use, while earth or rubble can be reused in site formation or reclamation if feasible.

6. RECYCLING

Apart from those valuable metals such as steel rebars and aluminum window frames, which have high scrape value, rubbles and demolished concrete can be processed into recycled rockfill or aggregates for use in construction. To avoid unnecessary waste of energy resources, only those materials with marketable value should be recycled. In most countries, 90% of the demolition construction materials consist of concrete and masonry, which are recyclable. Depending on the types of construction, some buildings were made of mostly masonry while some others were made mostly with concrete. To avoid mixing recyclable materials with nonrecyclable one, it is recommended to separate them at source by selective demolition and on-site sorting, as sorting highly mixed materials at the receiving ends is extremely expensive and not environmental friendly.

6.1 RECYCLING PRACTICE

Although different countries adopt different practices to suit their own situations, the recycling practices can be broadly classified in the following categories.

a. Adopting on site recycling and reuse with minimal import and export of construction materials for large reconstruction projects.

Examples:

I. During the reconstruction of super highways (outbound) in Germany, old concrete pavements were broken up and processed at a pre-planned nearby recycling site, with recycled aggregates used in producing concrete Grade 45 in an adjacent batching plant for use in new pavement construction. The advantages of this arrangement are:

II. Minimal export of waste and minimal import of raw materials

III. Minimal addition of traffic loading on existing busy road networks.

IV. Energy saving due to reduction on fuel consumption by lorries.

V. Reduced noise and air pollution due to least generation of traffics and fuel consumption.

VI. Maximization on the recycling potentials and values due to no mixing of high quality demolished materials.

VII. Adopting on site crushing with recycled products used in other projects or for re-sales.

VIII. Collecting and stockpiling recyclable materials, then hiring mobile crushers for processing.

IX. Establishing centralized recycling facilities.

X. Establishing recycling facilities within landfill site, with truck delivering C&D materials into the landfill site and collecting recycled products at exit (e.g. Denmark)

6.2 APPLICATIONS

Based on overseas experience and the experience in Hong Kong, recycled aggregates have lots of applications, running from high value applications such as use in concrete production and manufacture of concrete paving blocks and kerbs, to low end use as road sub-base materials, rockfill, filters, pipe bedding, in-fill to stone columns. However, the acceptance in high value application is slow in most parts of the world due to barriers and obstacles arising from conservatism and lack of confidence in using new construction materials.

Fortunately, the American Concrete Institution (ACI) and the European Union in the frame of RILEM" have been far-sighted enough to establish ground works on sustainable concrete with use of recycled aggregates. In Hong Kong at least 4 ready mixed concrete producers have experienced in producing recycled concrete up to Grade 40 for use in public works projects despite a slow start of using recycled aggregates in concrete production.

6.3 PROMOTION

Acceptance on using recycled materials takes time and promotion is required. Some overseas countries have taken 10 to 15 to develop the markets on recycling. In order to overcome the barriers and obstacles arising from conservatism and lack of confidence, education and information are the most important means to identify and exploit the opportunity on promoting recycling. It is necessary that the message and understanding of recycling be discussed at universities, technical institutes, amongst enterprises and public servants. Information centre should be set up for the transparent sharing of information and know-how on the development and use of recycled aggregates. In Hong Kong, the Government has taken the lead to liaise with the key players including concrete producers, contractors, academics and government department to collect information such as test data and research results for disseminating via the web connection

7.1 What is Selective Demolition?

"Selective Demolition" involves sequencing the demolition activities to allow the separation and sorting of materials. In general, domestic wastes such as furniture, household appliances, etc., metal components such as window frames, pipes, etc., timber components such as doors, wooden floors, etc., other wastes such as tiles, asphaltic materials, ceramic products should be removed one by one first.

The main demolition shall begin after all the above non-structural materials have been stripped and removed. As most old building blocks are built with brick walls on concrete frames, the percentage of brick is extremely high, ranging from 60% to 80%. To avoid mixing the non-recyclable bricks and tiles with the broken concrete, it is highly recommended to plan the demolition sequence such that brick walls are demolished first and stockpiled separately before the demolition of structural members.

7.2 What is On-site Sorting?

Without the implementation of selective demolition, all types of demolished materials will be mixed together. As a good practice, they should be sorted on-site and be separated into different groups including broken concrete, rock, bricks, rubbles, asphalt, soft inert material and non-inert waste. Sorted materials should be delivered to the recycling facilities as far as possible. In India, on site sorting is adopted by scrap merchants who sort, clean and even clean up resalable scrap. But C&D is left unsorted as they see no value and this ends up as land fill. However steel reinforcements are sorted and recycled.

7.3 What is On-site Crushing?

On-site sorting involves downsizing of large debris that has already been sorted. For this, small bucket crushers, crushing buckets and medium sized tracked crushers are available. The sorted down-sized C&D waste becomes a readily saleable material that can easily sold as sub-base or GSB for roads or sent to bigger recycling plants for further processing.

1. Sorted non-recyclable C&D materials delivered to public filling facilities for use as public fill for reclamation

2. Highly mixed public fill (both recyclable and nonrecyclable) delivered to public filling facilities.

3. Sorted broken concrete delivered to recycling facilities

4. Sorted broken concrete delivered to recycling facilities

5. Sorted non-recyclable C&D materials delivered to public filling facilities for use as public fill for reclamation.

6. Mixed demolished material results in recycling uneconomically and inefficiently

7. Sorted non-inert waste stockpiled separately.

8. Sorted broken concrete stockpiled separately

9. Sorted broken concrete stockpiled separately.

Fact Sheet on India

- By 2025 India will produce the maximum Waste in Asia according to 'Nature' journal.
- By 2025 Garbage Generation the world will reach 6 Million Tonnes/day and 2 Million Tonnes will come from Asia.
- By 2025, we might arrive at a situation where technology can handle almost all our waste, provided there is a disciplined effort all around. Some cities around the world are doing exactly that, now.
- By 2030, India will be the most populous country in the world.
- India will become the 'Garbage Capital' of the world by 2050.

Mixed demolished material results in recycling uneconomically and inefficiently

- Sorted non-inert waste stockpiled separately.
- Sorted broken concrete stockpiled separately
- Sorted broken concrete stockpiled separately.

With awareness in Waste reduction and recycling throughout the world, many researchers predict the peak garbage generation will reach around 2075.

- By 2100, India's waste generation will reach 70% of all high income and OECD countries put together.
- By 2100, all world cities together will produce 11 Million Tonnes per day, which is over 3 times today's figure.
- 'GARBOLOGY' the science of studying waste, is an academic discipline that is growing in importance.

New Demolition Rules to Assist Recycling (Proposed):

- Selective Demolition to be specified.
- On-site sorting to be specified.
- On-site crushing to be done for downsizing.
- Debris Management Plan to be insisted by all authorities.
- City / Municipality rules to be aligned for waste reduction and recycling.
- Central Recycling and Processing yard to be set up in every city over one Million population.

Need for Engineered Demolition using Modern & Machinery

- India's infrastructure in crumbling and new ones are to be built on war footing.
- All Metro cities are implementing infrastructure projects like Monorail, Metrorail, dedicated bus lanes,new airports, new ports etc.
- Dilapidated old structures have to be demolished for newer ones.
- Core industries like steel cement, paper, power are expanding and will need faster and safer demolitiontechniques.
- About 40,000 rail and road bridges need to be either demolished or retrofitted.
- India's slums are being replaced by affordable housing where densely populated areas will need precision demolition.
- Super tall buildings are being constructed in Mumbai, Bangalore, Chennai and New Delhi which will need special demolition methods at the end of their life.

11. CONCLUSION

Natural resources are not unlimited and will be depleted with time. Unnecessary wasting of natural resources should be restricted and regulated. Formulating and implementing proper waste management plan throughout the life cycle of the projects can minimize waste. With an integrated resource management, most of the construction and demolition material can be recycled and more natural resources can be conserved for our next generations.

The success on recycling and using recycled materials in high value applications required promotion by means of education and information, in addition to statutory mean.

Acknowledgements

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Construction And Demolition Wastes: Problems, Prospects and Tasks

(Presented at Convention of Builders Association of India)

K.S.JAGADISH, MANJUNATH AMALKAR, M.B.SOMANATH AND M.V.RENUKADEVI

INTRODUCTION

Construction and demolition wastes in urban areas pose several environmental problems. Firstly, one needs to find space for landfills where land costs are high. Low lying areas are usually selected for landfills which interferes with ground water recharge and also leads to excessive flooding. Loss of agricultural land is another problem, besides the cost in terms of energy & money in dumping the waste. Large urban centres also suffer from acute shortage of sand. Processing of C & D wastes offers an opportunity to mitigate sand shortage.

Table.1 lists the C & D wastes of various countries as reported by Chakradhara Rao et.al (1). It is a bit difficult to believe that India produces only 14.7 million tons of C & D wastes while even Hong Kong generates 20 million tons of waste per annum. A more systematic attempt to assess the availability of C & D wastes is needed.

TABLE-1: C & D WASTES AROUND THE WORLD

COUNTRY	ANNUAL C & D WASTES IN 106 T
U.K.	90.00
GERMANY	233.00
JAPAN	85.00
HONG KONG	20.00
CHINA	300.00
INDIA	14.70 (?)

C & D wastes have tremendous potential for recycling in producing building materials and building products. The CIDCO-YUVA building centre in Navi Mumbai has successfully demonstrated production of building blocks, interlocking pavers using demolition wastes [(2)].

Bangalore is one of the fastest growing metropolitan in this part of the world and it naturally involves generation of considerable C & D wastes. Fig 1 & 2 shows two rather ugly dumpsites near Bangalore.

Fig-1: Landfill site at Kengeri
(Land fill size ≈ 15m x 10m)

Fig-2: Landfill site at Byrohalli
(Land fill size ≈ 50m x 60m)

UTILISATION OF DEMOLISHED BRICK MASONRY WASTES (DBM)

Bulk of a demolished building constitute of brick masonry and concrete to some extent. The brick masonry contains about 60% of bricks and 40% 0f mortar and plaster. After crushing, the mortar and plaster will be reduced to sand while crushed brick will have both coarse aggregate and fine aggregate. The fine aggregate is actually "surkhi pozzolana" which has the property forming cementitious compounds when reacted by lime. The fine aggregate will have both sand and silt size particles. The C & D wastes from two sites were collected and crushed by hand to produce sand fraction material. The grain size distribution of the two samples are shown in Fig-3.

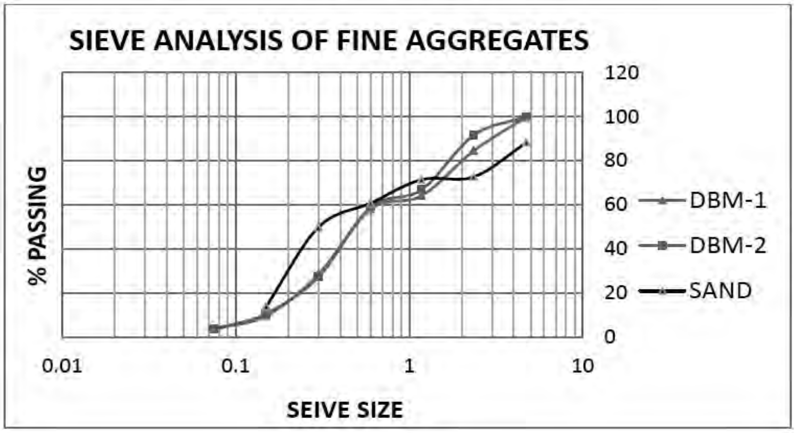

FIG – 3

(i) USE OF DEMOLISHED BRICK MASONRY IN MORTARS.

The crushed brick masonry waste (fraction below 4mm) is now mixed with sand in various proportions and 1:6 cement mortar is prepared with this mixture. The compressive strengths of the mortars for the two samples is determined by testing 5cm cubes. The strengths of the mortars at various ages is shown in Table.2. It can be seen that 50% replacement of sand by DBM fines gives best results, especially after 90days. This is due to the fact that the lime released by cement reacts with surkhi for a long period. It may even show higher strength after 6 months. The modulus however reduces with DBM addition.

TABLE-2. COMPRESSIVE STRENGTH OF MORTARS 5CM CUBES

Sl. No	Proportion of DBM in Sand	Age in Days	SOURCE - 1			SOURCE – 2		
			Cube Strength N/mm^2	Secant Modulus @ 25% of Ultimate Load N/mm^2	Moisture Absorption %	Cube Strength N/mm^2	Secant Modulus @ 25% of Ultimate Load N/mm^2	Moisture Absorptio n %
1	100%	7	1.7	-----	-----	2.19	-----	-----
		28	2.55	8200.00	21.05	3.79	7050.00	28.42
		90	5.60	-----	-----	6.04	-----	-----
2	50%	7	2.51	-----	-----	2.11	-----	-----
		28	4.28	8207.50	17.19	5.18	7602.00	19.82
		90	6.41	-----	-----	9.74	-----	-----
3	0%	7	2.81	-----	-----	2.53	-----	-----
		28	3.40	22,089.00	11.64	4.73	17,034.00	11.64
		90	----	-----	-----	6.29	-----	-----

This is however useful in brick masonry since our bricks have moduli in the range of 1000.00 to 2000.00 MPa. The moisture absorption, however, is rather high with DBM addition. This needs further investigation by addition of lime to neutralize brick powder and the effect of ageing on moisture absorption.

(ii) USES OF DBM IN CONCRETE

The DBM waste is now mixed with sand and coarse aggregate (20mm down) to produce concrete of grades 1:2:4 and 1:3:6. Again percentage of DBM was varied from 0% to 100%. Table-3 Shows the strengths of such concrete using DBM of Source-1.

TABLE-3 STRENGTH OF CONCRETE WITH DBM SOURCE -1

CONCRETE GRADE	1:2:4 N/mm^2		1:3:6 N/mm^2	
DAYS OF CURING → DBM% ↓	28 days	90 days	28 days	90 days
0%	17.41	—	9.19	—
50%	24.96	27.56	14.04	21.11
100%	23.14	28.27	15.26	18.52

It is clear that replacing sand partially by brick masonry waste we can get satisfactory concrete strengths. This issue of moisture absorption however needs to be explored further. Use of this concrete for making hollow or solid building blocks is definitely possible and needs to be attempted. This type of concrete is also eminently suited for foundation concreting and flooring concrete.

TASKS :

1. A pilot plant for processing of DBM by jaw crushing and sieving needs to be setup. This will help in evaluating the cost of such a process.
2. Such a pilot plant may be setup close to land fill sites.
3. Further research on long term strength and variation from site to site may be carried out to establish the reliability of the technology.

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New Equipments and New Technologies in Sand Manufacturing

Nagaraj K.V

Introduction

Sand referred in technical terms as fines aggregates is required in large quantities in various civil engineering projects for cement concerts, mortars, concerts blocks etc. In many areas, dredging creek gravel/river and then washing with creek water/ river water obtain it. Many a times, screening is also required to get required gradation of sand. All this process is an expensive and wasteful process.

Further more, it only slightly improves the physical properties of sand. No improvement in chemical properties can be achieved by washing/ screening. Also, there is no control on the quality of the sand and gradation of the sand. Now a days, Environmental ban on dredging operations has created a crisis for the construction industry in many parts on India. Generation of river sand is also stopped due to many irrigation projects, which control floods.

Present Situation

The quality of the sand available is given a cause for concern as it contains many a times very high percentage of slit, organic matters and some times other harmful chemicals like sulphates and chloride. Such sand has very high detrimental effects on structural As the proverb goes Necessity is the mother of invention can the present sand concrete. crisis set a modern construction industry to think to go for a better alternative for the scarce impure natural sand -can the quality sand be manufactured?

The answer to the problem is found in **Puzzolana SANDER & VSI.**

Typical Sand Plant !

The plant works on the principal of continuous feed in feed in closed circuit. The main reason of Opting for VSI is that it works on the principle of synonymous to production of Natural River sand. The natural river sand is produced by flowing of stones in big floods, right from mountains to nalahas to big river by collision of Rock on Rock thereby forming a mechanism of impact-cleavage-attrition-abrasion and then huge deposits are created. The vertical shaft Impactor Vertical Shaft Impactor (VSI) applies similar principle of Rock on Rock collision for crushing.

The Rock on Rock VSI uses a field proven rock lined rotor that act as high velocity pump hurling a continues rock stream in to a tightly packed rock lined crushing chambers. The rotor continuously discharge highly energized stone particles in to a highly turbulent particle cloud contained within the crushing chamber where reduction occurs primarily by Rock On rock impact, attrition and abrasion. Thus the process is very synonymous to nature process of creating sand.

The VSI does not require water to produce the sand. No dust is generated into the atmosphere from Impactor. However, a little dust generated from the vibrating screens and at discharge points that can be easily controlled by installing dust collector or simple water sprinklers.

Limitations of VSI

VSI due to its centrifugal force action which creates Attrition, Abrsion and Crushing to some extent generates micro fines which cannot be directly graded as SAND conforming to IS 383 doe the presence of -150 microns particle beyond the permissible limit of 20%.

This necessitates the need for Classification.

The classification can be done through Wet process involves large amount of water (4.2 Ltr/Sec for a 60TPH classifier) or Dry Air classifier which involves air as the medium.

SANDER

A comprehensive answer the growing demand of Sand is Puzzolana Sander.

Sander is a hybrid version of hydro cone crusher, which works on floating shaft principle. The main advantages of this Sander it works on gyratory motion similar to cone crusher and has a higher reduction ratio ensuring high productivity of Sand at a low operating cost. Sander can be installed in any existing crushing plant as a stand alone unit to produce sand.

Sander eliminates the need of classification as the micro fines generated is within the permissible limits of IS 383 Zone II.

Typical test report of Sand generated from Sander

CIVIL - AID

Ref:CIVILAID:FA: 2/2512 Date: 2.3.2013
Test Order dated: 28.2.13

M/s J & P Sand and Aggregates International Pvt. Ltd.
3/546V, St. Antony's Shopping Complex, Kizhakkambalam
Ernakulam 683 562

PHYSICAL TEST REPORT ON FINE AGGREGATE SAMPLE
(Manufactured Sand)

Source of sample	:	Sample supplied by the customer
Customer's Reference	:	Letter dated 28.2.13
Period of test	:	1.3.13 to 2.3.13
Project*	:	Not furnished
Condition of sample	:	Satisfactory
Test Method	:	IS:2386 (Part I to VIII)-1963 (Reaffirmed – 2007)

SIEVE ANALYSIS:

IS Sieve Designation	Cumulative Percent		Specification as per IS:383-1970 (Reaffirmed 2007) for Fine Aggregate (Percentage Passing)			
	Retained	Passing	Zone-I	Zone II	Zone-III	Zone IV
10.00 mm	0	100	100	100	100	100
04.75 mm	0.6	99.4	90-100	90-100	90-100	95-100
02.36 mm	20.3	79.7	60-95	75-100	85-100	95-100
01.18 mm	38.2	61.8	30-70	55-90	75-100	90-100
600 microns	55.1	44.9	15-34	35-59	60-79	80-100
300 microns	68.2	31.8	5-20	8-30	12-40	15-50
150 microns	81.3	18.7	0-10	0-10	0-10	0-15

REMARKS: The sample supplied satisfies the requirements of grading **Zone II** as per IS:383-1970 (RA 2007). According to IS:383-1970 (RA 2007) for Crushed Stone Sands, the permissible limit on 150 micron IS Sieve is increased to 20%. This does not affect the 5% allowance permitted in Cl. 4.3

* As furnished by the customer.

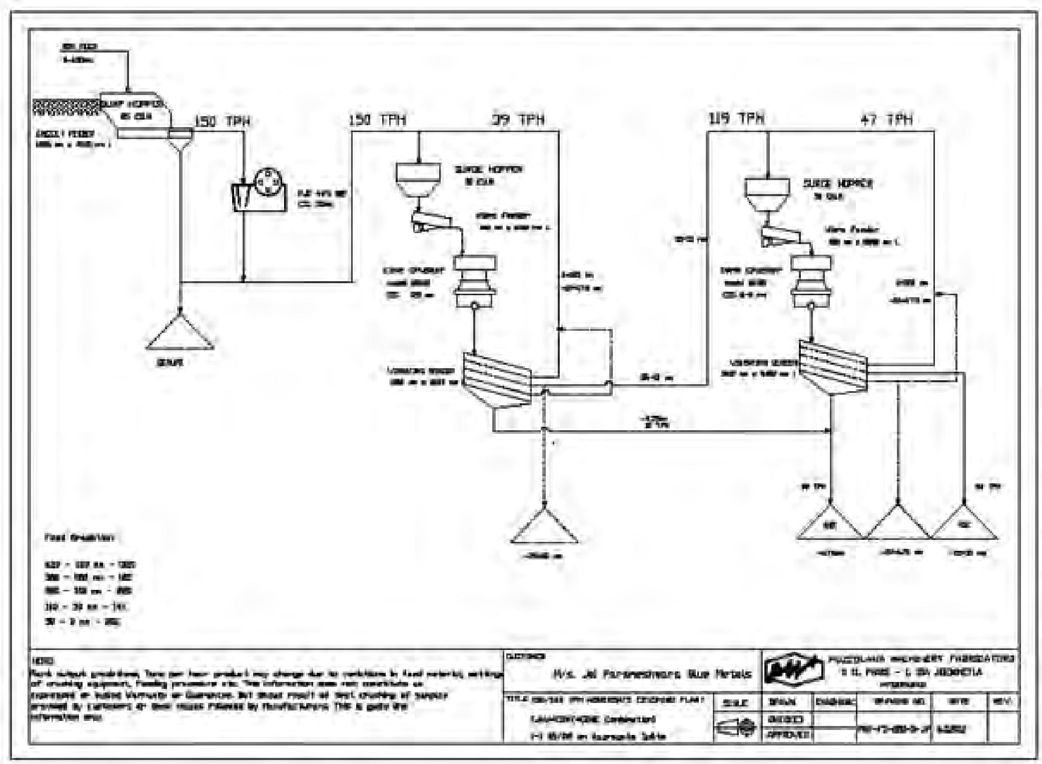
Note: 1. The results relate only to the items tested.
2. Report shall not be reproduced, except in full, without the written approval of the lab.
3. Any correction invalidates this report.

for **CIVIL AID TECHNOCLINIC PVT. LTD.**

2/3/12

RADHAKRISHNA
Sr. Technical Officer

Typical III stage plant with Sander introduced in the 3rd stage



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Classification Process

The classification process works with the aim to separate the fines that are generated during the production of sand. As we are aware air and water aides in sand formations in the nature , similarly mechanically the fines considered as (–)150microns that will be removed by WET or DRY process to bring the sand produced within the Zone levels specified in IS 383 for proper mixing of the final sand produced in concrete.

WET Process - Spiral Classifier Dry Process - Air Classifier


WET Process :

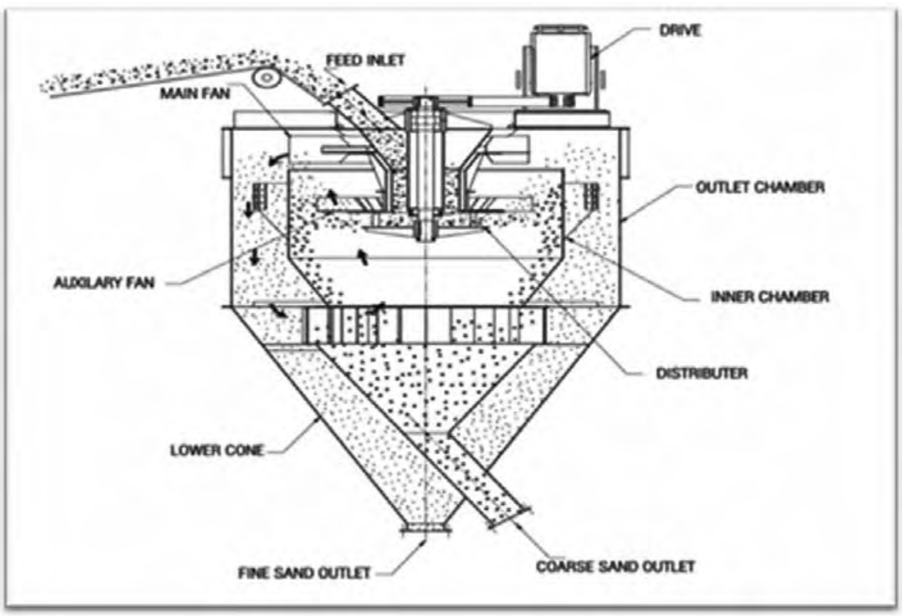
The Wet process circuit comes after the final product comes from VSI. Spiral classifier which is incorporated in the circuit for fines removal using a wet process and operates at cut size of –150microns and the over flow from the Spiral classifier.

The under flow of Spiral Classifier is made to pass through a Hi-Rate Thickener/Clarifier for separating the clarified over flow water can be reused in the plant, and under flow shall be fed to a Tailing pond.

Limitations of Wet Process:

Water	:	Requires too….. Much of water.
Water Re-Cycling	:	Cost of Huge size of Settling Tanks or Thickeners
Pollution	:	Sludge Management & Disposal.
Economics	:	High Maintenance & Operational Cost-expensive.

DRY Process :



Working Principle: The fines from the crushing plant is fed through feed inlet and dropped by gravity on the Auxilary fan. The Auxillary fan is connected to the drive motor through a housing. The Rpm of fan can be throttled through VFD fitted to the motor to control the amount of fines to be seperated. The main fan creates continuous circulating air into which the distributor disperses the fines.

Material acted upon the distributor plate is subjected to the following forces:

- Centrifugal force
- Ascending air force
- Gravity force

Fine particles up to a certain size are lifted by the ascending air current and pass between the blades of auxiliary and Main into the outer cone of the separator.

Underneath the separating zone there is return air vanes are located, the main fan moves the air to separating zone from the return air vanes.

The separation of fines can be attained by reduction is descending air velocity and also by adjusting the direction of return air vanes.

Heaviest particle will fall to the bottom of the inner cone which is classified Sand conforming to the standards prescribed in IS 383.

Air velocity , volume of Air and speed of Rotation are important factors to achieve the good seperation of fines from heavier particles.

Advantages Dry Classifer

CONSERVES WATER - No water consumption .

POLLUTION. Controlled hence less pollution.

USER FRIENDLY Easy operation and maintenance.

QUALITY CONTROL Speed can be varied according to the fine content in the input material .

GOOD ECONOMICS with less operational cost - Good Out Put.

Limitations

Subject to Moisture content in the input material .As per the available data it can operate up to 2-3% moisture by wt in the feed material.

Conclusion:

It is an established fact that the manufactured sand can be effectively used in all the above constructions activities. Also, the water demands to get the same workability, as in case of natural sands; is low. The cement consumption can be reduced by about 5-10%. The quality of concrete is better and long lasting as the inherit chemical reaction with salts by leaching etc which occurs in natural sands or filter sands does not takes place just for reference in the case of paints -the problems of efflorescence is addressed when M-sand is used.

We need to practice process which can be long lasting to achieve more productivity and better quality at low operating cost – Hope Answer lays with - Puzzolana Sand Producing Methodology and equipments.

Disclaimer :

Puzzolana /Trade vision association of individuals and groups working to develop a common awareness on manufactured sand Please be advised that nothing found here has necessarily been reviewed by people with the expertise required to provide you with complete, accurate or reliable information. . The content of any given article may recently have been changed, vandalized or altered by someone whose opinion does not correspond with the state of knowledge in the relevant fields.

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Experimental Investigations on Replacement of GBFS as Sand and GGBFS as Cement in Mortar

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1. INTRODUCTION

The concept of sustainable development includes, first and foremost, the judicious use of natural resources, which in some areas are rapidly depleting can be achieved by using industrial by-products and thereby reducing materials waste. Secondly, it is necessary to reduce energy consumption that is associated with carbon dioxide and other greenhouse gas (GHG) emissions, which are the primary cause for the well-known, ''green house effect". The production of Portland cement also releases large amounts of carbon dioxide and other GHG into the atmosphere [1-2]. For this reason supplementary cementitious material (SCM) are being used in concrete and its use would help achieve sustainable development. Ground granulated blast furnace slag (GGBFS), a by-product of the steel manufacturing industry is one such SCM in Portland cement concrete, either as mineral admixture or a component of blended cement. Due to its high content of silica and alumina in an amorphous state, GGBFS shows pozzolanic behavior similar to that of natural pozzolans, fly ash and silica fume [4]. Use of GGBFS in cement and concrete results in (i) improved workability and increased pumpability (ii) low heat of hydration (iii) increased strength (iv) reduced permeability and porosity (v) high resistance to chloride penetration, sulfate attack and ASR [3-7]. The increase in the amount of GGBFS content increases the required water of normal consistency and setting time of cement paste was extended with the increase in GGBFS content [8-9].

Granulated blast furnace slag (GBFS) is currently used in cement industry by grinding it. However, the total quantity of used material is not enough to spend all stocks. Grinding process is also an energy consuming process. Moreover, apart from using this by-product in ground form, using a non-ground form will give opportunity to use as fine aggregate. The use of blended cements with GGBFS in mortar or concrete manufacturing has been proposed by several authors [3-9], nevertheless its use as an aggregate in not so widely studied even if such action (reuse) would limit their landfill disposal. Only in recent years, some authors proposed the use of GBFS as aggregate in mortars or/and concretes production, they have found that good properties could be obtained if GBFS are used for partially or fully sand replacement material [10-14]. According to Neville [15] aggregates have a significant influence on both rheological and mechanical properties of mortars. Mineralogical composition, toughness, particle size distribution, shape and surface texture of aggregates are properties which affect the behavior of mortars in fresh and hardened state.

2. RESEARCH SIGNIFICANCE

In India, natural river sand (fine aggregate) is traditionally used in mortars and concrete. However, growing environmental restrictions to the exploitation of sand from riverbeds has encouraged the possibility of utilizing GBFS as a sand substitute in cement mortar. This serves as an effective technology for processing not only conventional concrete but also ready mix concrete from the point of sustainability.

3. EXPERIMENTAL DETAILS

2.1 Materials

Ordinary Portland cement of 43 grade conforming to IS: 8112 (1989) with a 28-day compressive strength of 56 N/mm2 is used. Properties of cement are presented in Table 1. Ground granulated blast furnace slag obtained from local factory is used. Its specific gravity is 2.82. The fine aggregates used for this work were natural river sand and GBFS. The physical properties of fine aggregates such as sieve analysis, specific gravity, bulk density, etc., were determined as per IS: 2386 (1963) as shown in Table 2. Fig. 1 shows the particle size distribution of the GBFS and NS, respectively. From the particle size distribution curve, it was found that both NS & GBFS confirms to grading zone II as per IS: 383-1970. Also NS and GBFS possess coefficient of uniformity (Cu) of 2 and a coefficient of curvature (Cc) of 0.88 which shows that both fine aggregates are well graded. In the present investigation conplast SP 430 super plasticizing admixture is used, which complies with IS: 9103-1979. The potable fresh water, which is free from organic substances, is used for mixing and curing of specimens.

Table 1 Physical properties of cement and recommendations for 43 grade cement

Properties	Test Results	IS:8112-1989 Requirements
Standard Consistency, %	31.5	No standard value
Setting time in minutes		
Initial setting time	120	Not less than 30
Final setting time	265	Not greater than 600
Specific gravity	3.14	-
Compressive Strength (MPa)		
3 days	32.67	23
7 days	43.20	33
28 days	56.67	43

Table 2 Properties of fine aggregate in SSD condition per IS: 2386

Properties	Natural sand (NS)	GBFS
Specific gravity	2.58	2.58
Bulk density, kg/m3	1610	1433
Water absorption, %	0.23	1.01
Fineness modulus	2.5	2.54

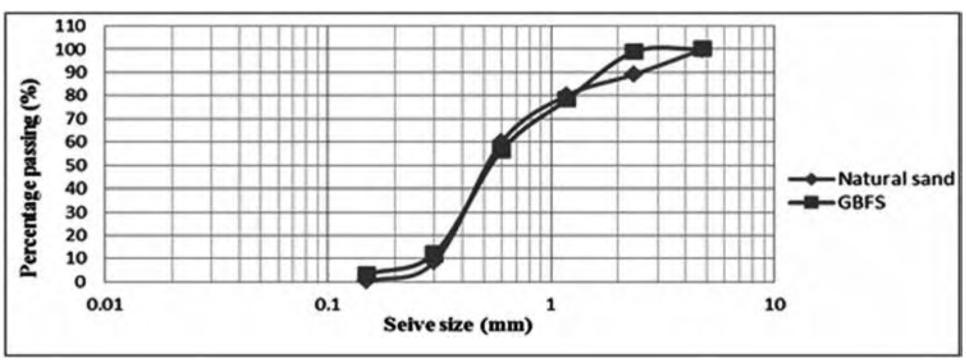

Fig. 1 Sieve size analysis for GBFS and NS

3.2 Mix proportioning

Three levels of replacement of GBFS were adopted in this study to replace natural sand, namely 25, 50 and 100%. The proportions of constituent materials used for mortar flow are shown in Table 3.

Table 3 Proportions of constituent materials used for mortar flow

Combination	Cement (g)	Natural sand (g)	GBFS sand (g)	Water(ml) (w/c-0.4)	Water(ml) (w/c -0.5)	Water(ml) (w/c -0.6)
Reference mix (0%replacement)	200	600	0	80	100	120
100% replacement of natural sand with GBFS sand	200	600	0	80	100	120

3.4 Testing

3.4.1 Consistency and setting time of cement pastes

The consistency and the setting time of fresh pastes were tested according to IS 4031. The setting process reflects the gradual change from a plastic mix to a stiff one, and is a result of the hydration process, whose products gradually interconnect the separate solid particles into a network structure.

3.4.2 Flowability of Cement Mortar

Workability of fresh cement mortar was measured by using standard flow table apparatus as per IS: 5512.

3.4.3 Compression test

Mortar specimens were produced by mixing one part of the cement with three parts of sand, using a water-to-cement ratio (w/c) of 0.50. The mortars prepared were cast into 70.7 x 70.7 x 70.7 mm moulds as per IS: 4031 (2000). The compressive strength test was carried out at the ages of 3, 7, 28 and 90 days according to IS: 516.

4. DISCUSSION OF TEST RESULTS

4.1 Consistency and setting time of cement pastes

Table 4 shows the test results from the determination of consistency and setting time for cement pastes. Consistency of the cement paste in combination with GGBFS increases as the percentage of GGBFS content increases. It means for a given penetration of 5mm to 7mm we need to add more water as the percentage of GGBFS increases. From the setting time data in Table 4, it is clear that cement in combination with GGBFS retards the initial and final setting time due to the excess of mixing water with respect to corresponding Portland cement. These results are in good agreement with those reported by Heikala et.al [8].

Table 4 Consistency and setting time details of cement pastes

Cement mixes	Consistency (%)	Initial setting time(min)	Final setting time (min)
100% cement + 0% GGBFS	31	120	265
80% cement + 20% GGBFS	31	122	292
60% cement + 40% GGBFS	32	157	340
40% cement + 60% GGBFS	34	187	367
20% cement + 80% GGBFS	34	190	395

4.2 Flowability of Cement Mortar

The variation of flowability containing different percent replacement of GBFS and for different w/c ratios is shown in Figs. 2 - 4. The results indicated that the use of GBFS at any level of replacement as a fine aggregate in cement mortar will significantly reduce the flowability of cement mortar. The reduction in flowability is attributed to the fact that the sand has been replaced by a finer and a more absorbing material. As the finer material increases, more is the surface area and hence more water is required for wetting the surface. For the given fixed quantity of water as the finer material increases the flowability decreases. The decrease in

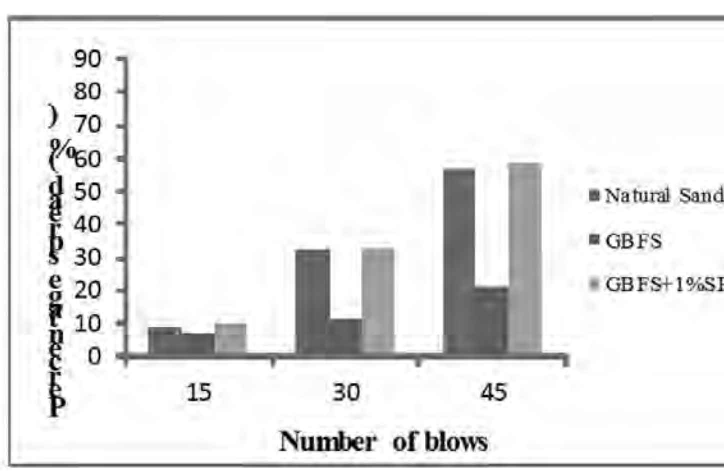

Fig. 2 Variation of flowability of mortar for different type of sand at w/c of 0.4

flowability is also due to uneven surface characteristic as well. This flowability can be increased by adding certain dosage of superplasticiser. From Figs. 2 - 4 it was observed that by adding 1% of superplasticizer by weight of cement, it was possible to get workability closer to that of reference mix.

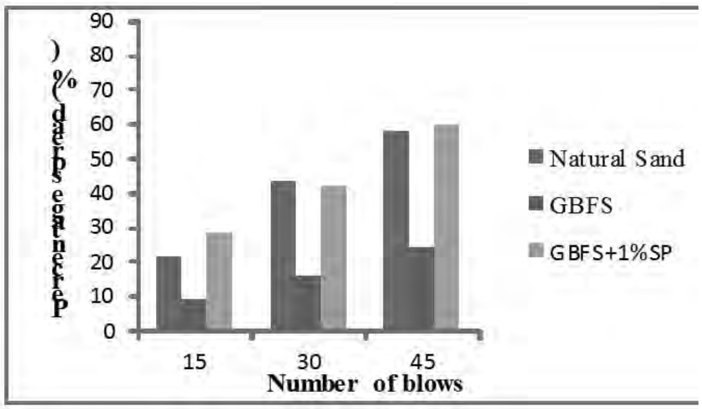

Fig. 3 Variation of flowability of mortar for different type of sand at w/c of 0.5

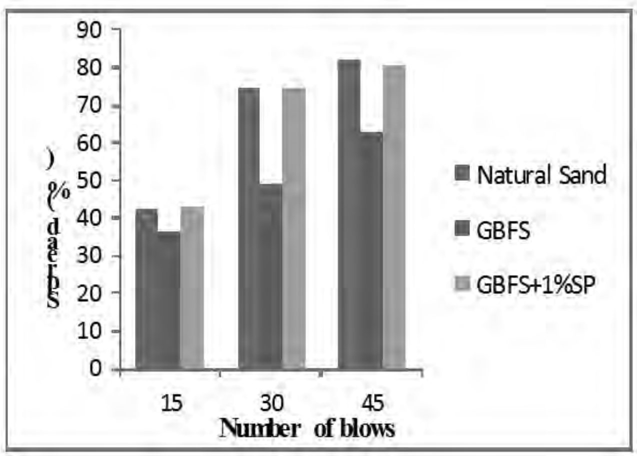

Fig. 4 Variation of flowability of mortar for different type of sand at w/c of 0.6

4.3 Compressive strength

Experimental results of compressive strength for each mix are reported in Table 5. The percentage reduction in compressive strength of mortar for Different Replacement of NS by GBFS in relation to the control is expressed graphically in Fig. 5 to show the level of strength loss. This loss in strength is attributed to the increase in surface area of the fine aggregates requiring more grout to coat the surface of the aggregates. This trend agrees with results reported elsewhere [8–9]. These results clearly indicate that, to an extent of about 25% and 50% GBFS can be used as a replacement of NS but 100% replacement of NS by GBFS reduces the strength of mortar drastically. Figs. 6-8 show the effect of GGBFS on the compressive strength development of mortar. The results indicate that, there is a systematic decrease in compressive strength as the GGBFS content increases during the early stages of hydration. At early ages (up to 7 days), GGBFS acts more as a filler material and nucleus for precipitation of cement hydration products than as a cementitious material. Beyond 28 days and up to at least 90 days, the presence of GGBFS is highly beneficial at 20–60% replacement with strength slightly lesser or similar than that of the control. These results came from the fact that GGBFS, which is latently hydraulic, undergoes hydration reactions in the presence of water and calcium hydroxide, $Ca(OH)2$. This secondary pozzolanic reaction yields a denser microstructure because the $Ca(OH)2$ is consumed and C– S–H paste is formed. A noticeable strength reduction at all ages is observed at 80% GGBFS. This trend agrees with results reported elsewhere [3–7]. The slightly varying results reported were mainly due to the chemical composition and the fineness of GGBS used in each study.

Table 5 Average compressive strength of mortar mixes at different testing ages (N/mm²).

Mix No	Mix Type	3-day	7-day	28-day	90-day
M_1*	(100%C+0%GGBFS) : (100%NS+0%GBFS)	25.2	33.5	52.1	65.1
M_2	(100%C+0%GGBFS) : (75%NS+25%GBFS)	23.1	31.2	51.0	59.7
M_3	(100%C+0%GGBFS) : (50%NS+50%GBFS)	22.2	30.8	49.5	59.1
M_4	(100%C+0%GGBFS) : (0%NS+100%GBFS)	16.6	23.7	35.4	46.8
M_{1-1}	(80%C+20%GGBFS) : (100%NS+0%GBFS)	18.6	29.4	47.5	55.1
M_{1-2}	(60%C+40%GGBFS) : (100%NS+0%GBFS)	13.6	22.5	36.1	51.9
M_{1-3}	(40%C+60%GGBFS) : (100%NS+0%GBFS)	12.3	20.2	31.0	46.0
M_{1-4}	(20%C+80%GGBFS) : (100%NS+0%GBFS)	9.2	13.1	17.6	19.5
M_{2-1}	(80%C+20%GGBFS) : (75%NS+25%GBFS)	21.3	27.7	47.1	59.1
M_{2-2}	(60%C+40%GGBFS) : (75%NS+25%GBFS)	15.9	23.7	45.9	56.1
M_{2-3}	(40%C+60%GGBFS) : (75%NS+25%GBFS)	12.3	20.9	37.5	45.5
M_{2-4}	(20%C+80%GGBFS) : (75%NS+25%GBFS)	8.3	13.2	18.7	21.8
M_3	(80%C+20%GGBFS) : (50%NS+50%GBFS)	23.5	30.9	48.9	56.4
M_{3-1}	(60%C+40%GGBFS) : (50%NS+50%GBFS)	17.5	24.1	43.3	53.6
M_{3-2}	(40%C+60%GGBFS) : (50%NS+50%GBFS)	15.2	22.3	37.7	48.8
M_{3-3}	(20%C+80%GGBFS) : (50%NS+50%GBFS)	13.4	18.5	23.6	27.6
Note: M_1* means Control mix					

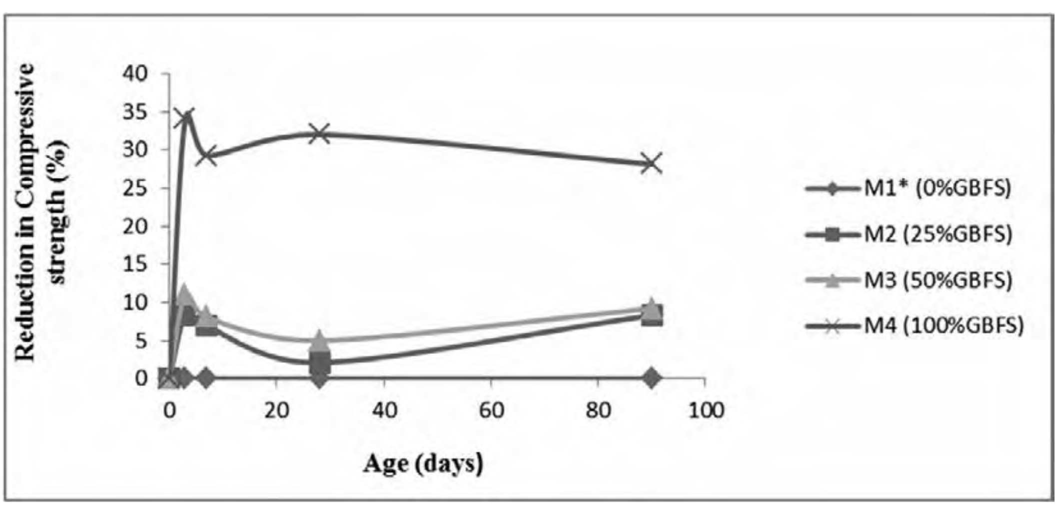

Fig. 5 Percentage reduction of compressive strength for Different Replacement of Natural Sand by GBFS Sand

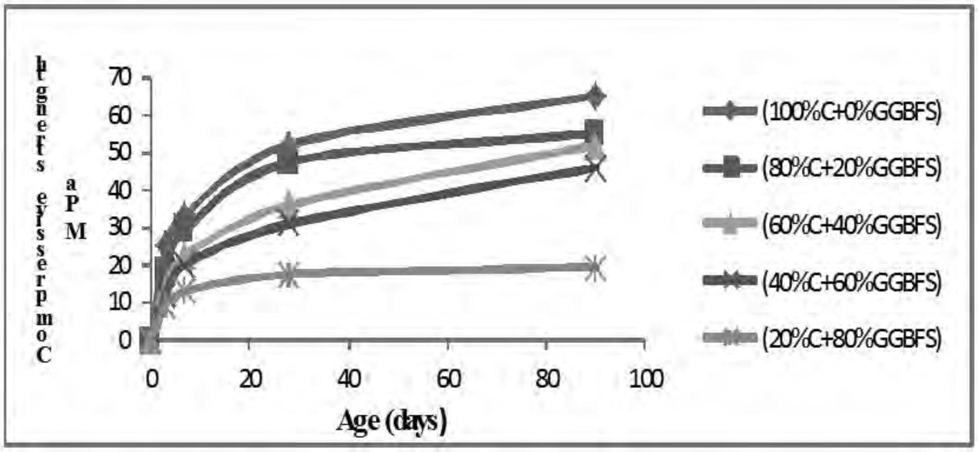

Fig. 6 Effect of GGBFS on compressive strength development (100%NS+0%GBFS)

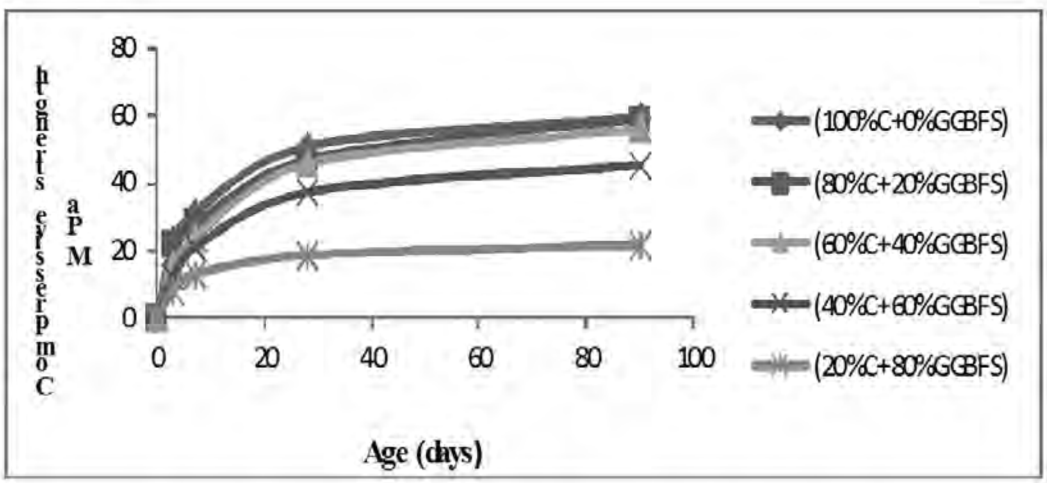

Fig. 7 Effect of GGBFS on compressive strength development (75%NS+25%GBFS)

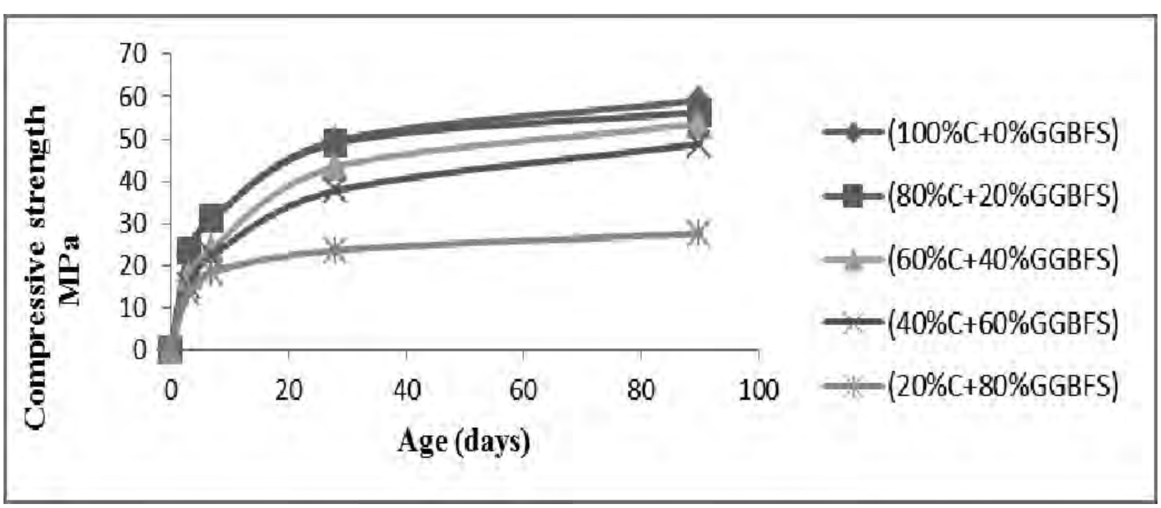

Fig. 8 Effect of GGBFS on compressive strength development (50%NS+50%GBFS)

4.4 Application of generalized Abrams law

The compressive strength of the mortar can be adjusted by varying the w/c ratio as long as the mix is workable. Superplasticizers can be used to get the required workability of the mix, if necessary. As found in the earlier investigations [16, 17], the strength of the cement mortar depends on the w/c ratio with all other parameters remaining the same. If the strength of the mortar is known at the w/c ratio of 0.5, the w/c ratio required for any other level of strength of mortar can be determined using the following relations with a single experimental strength.

S/S0.5 = - 0.2 + 0.6 (c/w) for S0.5 > 30 MPa ------------ (2)

S/S0.5 = - 0.73 + 0.865 (c/w) for S0.5 ≤ 30 MPa ------------ (3)

where S= Compressive strength at any water-to-cement ratio

S0.5 = Compressive strength at water-to-cement ratio of 0.5

w/c = water-to-cement ratio

This exercise is designated as 'Re-proportioning Method' [17, 18]. Since the Portland cement and GGBFS are interacting particulate materials, it is possible to account for its combined interaction by Generalized Abrams law instead of water/cement ratio, water/cementious material (Cement+GGBFS) ratio. The matching of microstructure in terms of porosity for a specified age is the basis of this approach. The premise is that for a particular level of strength at an age, say 7 or 28 days which is associated with a specific level of porosity. Since the rate of strength development of GGBFS cement mortar mixes was slower at the same age that is strength development is lesser (Table 5). For example, the 28 days strength of M1* mix at w/c ratio of 0.5 is 52.1 MPa. With 40% GGBFS, the strength at same w/(c+ggbfs) ratio of 0.50 its 36.1 MPa. To jack up this value to 52.1 MPa, the available space to fill up by hydrated gel is to be lesser. Thus by using Generalized Abrams law and data of GGBFS to cement mortar mixes, the calculated water/cementitious material ratio is 0.365 instead of 0.5. With this reduction at the age of 28 days, the gel space ratio (porosity) would be same as that at 0.50 M1* mixes. The strength obtained by M1-2 mortar mixture has been 49.1 MPa (Table 6 and Fig. 9). The same principle has been used to match the strength of M3-2 at 28 day (Table.6 and Fig.10).

Table 6 Strength results of reproportioned mortar mix

Jack up	Mix Type	3-day	7-day	28-day	w/c
1	M1*	25.2	33.5	52.1	0.5
	Based on 28 days strength of M1-2 to 28 day strength of M1*	25.4	34.7	49.1	0.37
2	M2	23.1	31.2	51.0	0.5
	Based on 28 days strength of M2-2 to 28 day strength of M2	25.2	33.6	50.2	0.48

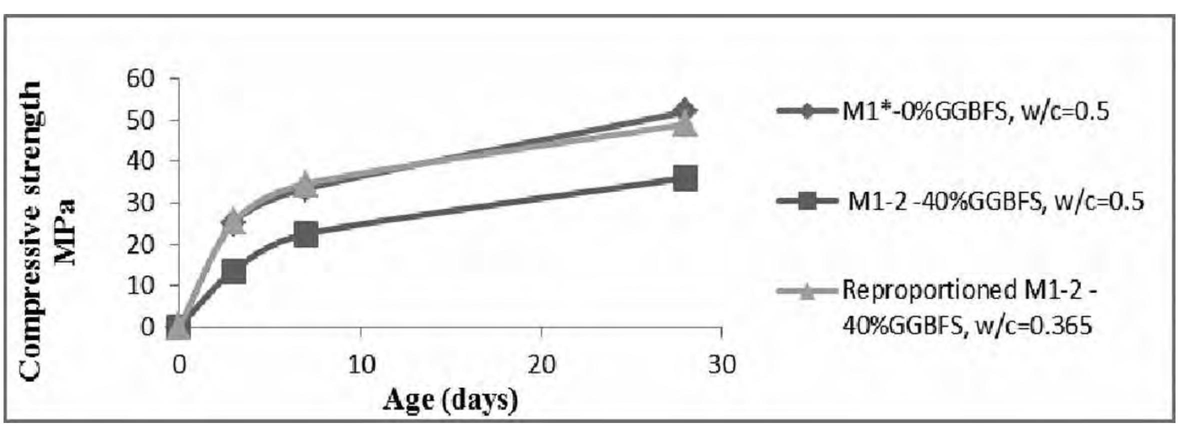

Fig. 9 Reproportioned 28 day strength of M1-2 to 28 day strength of M1 (100%NS+0%GBFS)

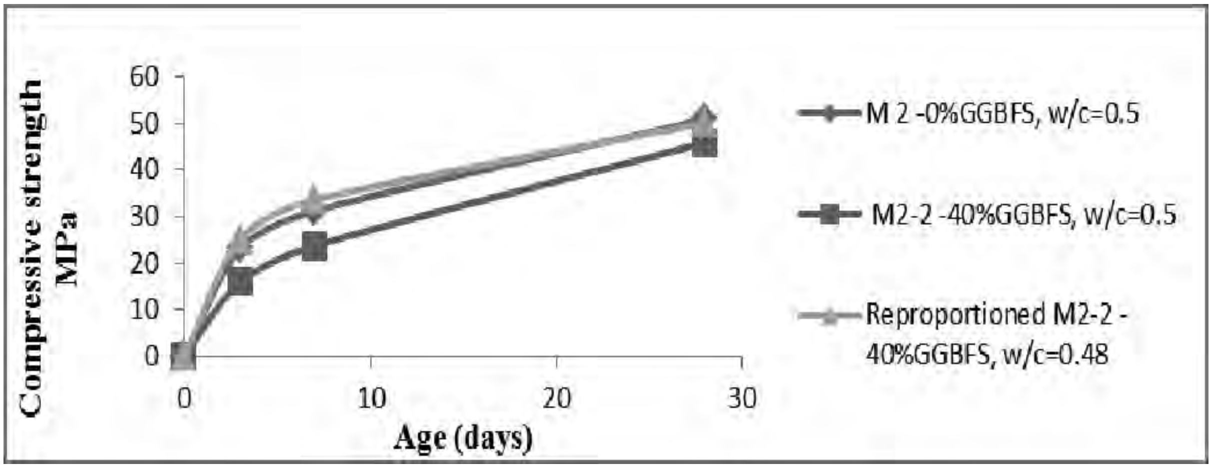

Fig. 10 Reproportioned 28 day strength of M2-2 to 28 day strength of M2 (100%NS+25%GBFS)

5. CONCLUSIONS

The following conclusions are drawn from the results of this investigation:

- Consistency of the cement and setting time of the cement in combination with GGBFS increases as the percentage of GGBFS content increases.
- The flow of mortar decreases as the percentage of GGBS increases. The decrease in flow for 25% is marginal and for higher percentages, the flow decreases substantially. Using suitable dosage of chemical, the flow can be maintained.
- Compressive strength of the mortar with GBFS decreases marginally compared to the control mix consisting of natural sand. Based on the observation, to an extent of about 25% and 50% GBFS can be used as a replacement of NS but 100% replacement of NS by GBFS reduces the strength of mortar drastically.
- In an average 50% of cement and 50% of NS can be replaced by an equivalent part of GGBFS powder and GBFS sand can be used without sacrificing much of the properties of control mortar.

The above samples are tested for the durability properties such as porosity, permeability and sorptivity. However the results are not presented and it is found that as the percentage of GGBFS increases, the internal voids increases and the initial rate of absorption also increases, which clearly indicates that the quality of slag is inferior.

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New Technologies in Crushing Systems

Shyam Prasad M

India has undergone rapid development of Infrastructure in last 15 years. World's leading technologies have been part of the India story. In Crushing / Rock processing technology, Indian construction companies mostly had primitive machines and unscientific processes that mostly made aggregates not adhering to any standards of shape or gradation. With the wave of liberalization and successive governments' push to the mega Infra projects followed by implementation of tight specs (especially in road sector), World's leading technologies started arriving in to the country. Capacity, Availability, Meeting Stringent Shape/ Gradation requirements, and more recently, Automation are the new requirements by the aggregate producers.

The dwindling availability of river sand and strict enforcement of sand mining laws, made the construction companies to go for alternatives like Manufactured sand – which is produced by a scientifically designed rock processing plant to meet the specs of gradation, and shape. Crushing rocks (that size up to 1000mm), to below 05mm, while adhering to quality norms, in a matter of minutes became the new possibility in numerous cities that were starving for Sand in construction activity

A Reflection towards the past

Most of the construction companies, or commercial aggregates suppliers had series of jaw crushers, and at the most, horizontal shaft impactors in the rock processing set-up. A rated capacity of above 50 metric tons/hour was a rarity. Screening was most primitive; as barrel type rotating screens were used. The shape and gradations were mostly unheard off, and natural sand was used in concrete.

Concepts like Plant Availability (for production), Efficiency (of capacity and quality) and Service (help a call away, even for the remotest project sites) were almost non-existent.

New Technologies

With the introduction of mega projects, construction companies, happily went shopping mega machines produced by the expert companies with years of rock processing focus & expertise. For example, metso - the worlds' leading crushing solution provider, was born in pre-war Europe (metso's predecessor companies) and has decades of experience in varied applications around the world. Rock processing plant capacities like 100 metric tons per hour suddenly became the "small plant" in the new crushing fraternity parlance, as Infra projects demanded capacities that were 200 metric tons per hour onwards! Cheap-to-purchase, but expensive-to-run machines like Horizontal shaft Impactors started fading away from the plants, as the crushing costs came down, with increased productivity and capacities.

Jaw Crushers:

Modern Jaw Crushers are of simple, single toggle construction with no hassles of old-fashioned oil bath construction. Jaw Crushers are the first stage of rock size reducers and typically work in the crushing ratio of 4:1. Features like mechanical / hydraulic gap setting adjustments have made machine's availability higher.

Cone Crushers:

Followed by the jaw crusher, most of the modern plants now have a hydraulic cone crusher in the secondary Stage of Crushing. A Cone Crusher can easily do the work that would otherwise need multiple set of jaw crushers.

Advantages of cone crusher include,

- Better shape of produce
- Better availability, Hydraulic operation
- Simple & Compact Crushing process
- Lesser manpower needs
- Lesser power requirement

Fixed Shaft Cone Crushers

In last 3~4 years, aggregate producers are shifting their focus towards the new generation HP type of cone crushers. These fixed shaft type cone crushers are specially designed for "mining duty" applications that demand higher crushing force than normal cone crushers to get superior reduction/ shape.

Rock on Rock VSI Crushers

The technology of energized rock particles hitting other rocks, to break into cubicle aggregates and superior quality Manufactured Sand has become very popular across India. The Barmac type of Crushers produce sand that fits easily in to IS sand specs. The sand granules and aggregate product fractions made from Barmac are cubicle / roundish which make the pumping of concrete easy.

Usage of Alloy Steels and Wear resistant materials like tungsten carbide in the wear parts of high speed rotor inside the VSI crusher, ensure lesser down-time and wear life that runs in to several thousand tons of rock processed.

High Efficiency Screens:

Screens that separate various sizes of coarse/fine aggregates are very important equipment in the rock processing set-up. Modern, highly efficient screens have replaced their rotary type counterparts that were so ubiquitous in older crushing plants. Applying various types screens (circular motion, elliptical motion, banana screens, primary screeners, Scalpers and new generation high frequency screens) that are suitable for various application needs at various stages of crushing ensure high quality and efficiency in grading the product fractions. Mechanically too, the modern screens are less maintenance prone – as the days of oil bath type of screens have gone and most of the modern screens needs simple greasing schedules on the modular type vibrator mechanisms.

With the modern screens came the special application of screening media that can lasts several times the normal steel wire media. Some of the plants now use only rubber / flexible rubber/ Poly Urethane media to reduce the down-time that is incurred during frequent changing of the steel wire meshes.

Wet Washing : Sandtraps

Some Concretes require sand having not more than 10% of ultrafines (material passing 150 microns). To limit the ultrafine rock particles in the sand, the sand has to be washed. Sandtraps have conventional sand screw, integrated with PU bucket wheel agitator –cum- lifter and a dewatering screen in a single set-up to efficiently wash of the ultrafines.

Air Wash – Latest Air Classifiers

The requirement of water for wet washing and the associated issue of handling and disposal of wet slurry containing ultrafines has made the industry to look at Air Classifiers. Air Classifiers need no water for separating ultrafines from the Manufactured Sand.

The maintenance needs of metso air classifiers is very minimal as there are no rotating or moving parts in the classifier. The ceramic wear parts inside the classifier last for many years. Compared to wet classification, the air classification has the advantage in constructing the gradation of the end product (ie, classified manufactured sand) as it can effectively limit the ultrafines to the quantity desired by the end user/ concrete mix design.

Rock Test Facility

One of the important aspects for the end product getting accepted in the market is the quality of the source rock. For testing the physical properties, various labs – private as well as, University labs can help. However, crushing specific terms like Crushability and Abrasiveness can be tested at the labs of solution providers. The rock tests help in fine tuning the crushing process, knowing the power requirements and deriving the expected wear costs to understand the economics of crushing – very much before the installation / purchase of the crushing plant

Computer Simulation Software

The days of 'crusher mistry' advising on the process are gone. Now we have computer simulations (developed by the manufacturers or industry software) with thousands of field data of installed applications combined with rock properties, that help sizing the crushers, screening area, and material handling equipment. With the help of rock test data, even the power needed for each stage of crushing can be arrived at, using the results of the simulation. The expected gradation, %ge of various product fractions can also be simulated.

Automation & Safety Considerations in Crushing & Screening Plant

To achieve consistency in quality, automation has become a tool. From a simple automation like having an electrical interlocks between successive equipments in the process, to operating plant completely under a PLC – automation can be applied in various degrees suiting different needs.

Presently automation is used mostly as a safety tool – especially in the Barmac rock – on – rock VSIs or in cone crushers. The Barmac VSI has a spinning rotor that rotates at high speeds (in excess of 1400 rpm), with many wear parts on. Operators find it increasingly useful to go for the automation that observes the vibration, temperatures etc, real time. The systems constantly displays the data to the operator, and in case of any issues, shuts the machine down.

In case of cone crushers, Intelligent Control Automation, help in monitoring the efficiency and safety of the equipment. Crusher settings can be changed, on load, in a matter of seconds to adjust the end product fractions. The system even helps in trouble-shooting as it indicates the problem areas to the operator for quick attention.

Choke feeding the crushers (or operating the crusher at its full load, with crushing chambers full) help in getting productivity and yields excellent end product shape. Modern plants have surge bins with feeders that control the crusher's feeding rate by ramping up/down of the frequency of the feeder, automatically.

HSE is the new buzz word in the industry. Safety tools like pull chords, overload protections, emergency buttons at each crushing stage, self cleaning camera's over each crushers/ screens/ surge bins – all help in operating the plant safely, at highest efficiency.

The industry is facing acute shortage of manpower with not many younger generation workers willing to enter the mining and quarrying streams. The unavailability of the local manpower, combined with high attrition rate amongst the "mobile" work force has curtailed businesses. Automation not only adds consistency to the process, but at the same time, reduces manual intervention in the process.

Mobility

Infra companies, specifically in road segment, and Iron ore export firms in mining saw the need of full or partial need of mobility of the crushing & screening equipment. In the middle of last decade, the wheel mounted crushing plant became a norm in the road sector. Recently, the demand for fully mobile crawler mounted crushing and screening equipment are gaining ground. Manufactures have also responded well, by putting up the factories in India and starting the production of the wheeler and crawler units, making these units affordable.

Technical Support and After Sales Service

Indian private businesses are known for quicker actions and taking quicker decisions. They expect timely availability of parts and services, for the latest technologies that they purchase. Battery of strategically located regional service engineers, and warehouses that stock spares and Wear'ss, has become a necessity for the manufacturers. Companies like metso have invested in foundry that manufacture the alloy steel wear parts, with metallurgists preparing 'alloy recipe' for some of the toughest, abrasive rocks.

Unit Equipment Solutions

Latest development, in the last couple of years since the economy has slowed down, is the trend of Unit Equipment retrofits in the existing plants. There have been success stories, where customers replaced a series of jaw crushers / impactors with a modern cone crusher or an inefficient screen replaced by the efficient, vibrating screen. While the customer finds it affordable to purchase only a single equipment to increase / better the productivity, the manufactures get chances of expanding business opportunity in a new segment.

Conclusion

While the Industry is looking for tools to boost efficiency and availability, with quality end products; Manufacturers task is cut-out in offering the new but proven technologies from their global product portfolio - to yield best cost/ton, with fast service backup. Automation will ensure quality, with least manual intervention. Crushing is simple technology, if there are right machine at the right stages of the crushing plant. From railway ballast to the finest plaster sand, any type of aggregate/ sand can be produced with the new technologies that are available now.

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Why manufactured Sand?

Source : RESULTS Minerals & Aggregates - METSO

David Morrow

Globally, piles of manufactured sand are about to grow significantly in the near future.

Why manufactured sand?

Globally, natural sand and gravel extraction is becoming less of an option. New pit location opportunities are fewer, further from the marketplace and harder to secure. In the past, natural sand and gravel extraction has been the backbone of the aggregate industry; this is increasingly less the case. Operators now wish to produce high-quality manufactured sand. Why? There are two main drivers.

Firstly, there is a lack of natural sand reserves. Urban expansion, local legislation and environmental constraints have made the extraction of natural sand and gravel an expensive activity. Application processes for greenfield sand and gravel extraction are often long, expensive affairs with a high chance of site applications being rejected.

The increasing difficulty in extraction has had a negative effect on the bottom line for many producers. Concrete plants require a consistent, quality sand to optimize their production and minimize their cement usage. In many regions of the world, the extraction of sand and gravel is heavily taxed or banned completely to try to preserve remaining deposits. The industry must find alternatives to meet the growing demand for fine aggregates.

Urban expansion and depleted resources have increased the distance between the point of extraction and the point of use. Road congestion has increased the travel time from pit to batching plant for many operators. This, coupled with a decline in the number of pits, has increased prices for the end consumer. The second driver is purely economic. A growing number of quarry operators have found that processed, high-quality manufactured sand can improve their bottom line and significantly reduce the percentage of waste and low-value by-products. Customer requirements for production less than 20mm, especially for 7/10mm, mean that significant amounts of 0/7mm are produced as a by-product.

By utilizing the correct process equipment, low-value crusher dust can be processed into a high-value, premium product. Concrete, mortar and asphalt sand production is possible depending on the material characteristics and regional regulations.

The benefits of this process are twofold: the producer secures new product offerings and reduces low-value product; and the customer has access to a secure supply of sand with a stable grading curve.

End product performance

Production of high-quality manufactured sand requires specialist knowledge in fine crushing and separation technology to achieve end-product performance. Processing is the key to producing a marketable product. The production of quality manufactured sand, along with its process and process control, is integral to customer success.

The two factors that are of the greatest concern to the end users of manufactured sand are compliance with local regulations and the consistency of the product. Compliance with manufactured sand gradation is required not only at the bottom of the curve, but throughout the product envelope.

Product consistency allows a more predictable mix to be produced than is achievable with natural sand due to normal natural variations in dug sand gradation.

This means that end users of manufactured sand don't have to allow a safety factor to mitigate for natural gradation variations and can achieve binder savings. Sand solution equipment Operators generally have exacting requirements.

Specifications vary from region to region and successful implementation of manufactured sand differs from operator to operator. Solutions should be modeled on best practices to meet what the market requires.

Metso provides complete crushing and separation solutions for greenfield sites or solutions that can be incorporated into existing plants to achieve well-graded, quality manufactured sand.

Cone crushing technology gives the producers high energy efficiency and capacity, good product gradation, a high reduction ratio and low sensitivity to rock hardness.

Cavity design for cone crushers should be optimized to ensure that crushing occurs along the full length of the crushing zone between the liners. This causes interparticle crushing to occur, leading to the highest possible generation of the required fines and cubically shaped products.

Advances in high-speed cones with high clamping forces offer the opportunity to produce well-graded and shaped <20mm product including well graded manufactured sand. Vertical shaft impact (VSI) crushing technology has the advantage of being able to process fine, unscalped, heterogeneous and irregular feeds. Unlike cones, VSI shaping is not influenced by the closed side setting (CSS), and shaping occurs throughout the product curve.

The sand produced from rock-on-rock crushing is proven to have sound performance in concrete and mortar products. Such sand is well known for its cubical shape and consistent gradation. The gradation and quality of the product from the VSI does not tail off with increased wear on parts. This leads to the highest possible quality of performance in concrete and mortar mixes leading to reduced production costs.

Air classification technology

The global trend is to utilize dry classification solutions to produce manufactured sand. The dry separation process separates fine and coarse particles. This allows a reduced percentage of superfines in manufactured sand, thereby meeting specifications and achieving quality products.

Air classification is a vital aspect inthe production of manufactured sand. Two AC27 gravitational inertial classifiers and one AC18-9C classifier in a parallel/series configuration.

Metso offers aggregate producers two classifier options. The gravitational inertial classifier is typically fed 0/4mm or less and makes separations between 300 microns(50#) and 63 microns (230#). These units are ideal for use in the manufacturing of concrete and asphalt sands that typically require a reduction in the amount of 63 microns (230#) present. This unit is designed with an internal recirculating function that allows the efficiency of the separation to be adjusted depending on the desired grading curve.

When finer separations are required, the centrifugal classifier can make separations of between 100 microns (140#) and 20 microns (625#). This makes these units suitable for the production of very fine products such as lime, fly ash and fertilizers.

Metso's air classifier range provides versatile, economic technology that can be combined with a range of different crushing and screening equipment to produce a tailored plant. It allows for the production of dry products so there are no dewatering or drying costs. Process water is not required, which significantly reduces the quarries' water demand, settling pond requirements and makes arid regions viable.

No moving parts and ceramic linings mean exceptionally low maintenance and wear parts costs, even with the most abrasive of rock types. Highly efficient separation, even at very fine particle sizes, produces quality product and limits the amount of product in waste.

Manufactured sand has a more predictable product consistency than natural sand variations.

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Ready Mixed Concrete Using Alternative Fine Aggregates And Quality Certification For Manufacturing

Aswath M U

The Current concerns of the construction industry are the Speed of construction and Quality of Concrete produced. Due to the technological changes, the need for High Strength & High Performance Concrete, Self Compacting Concrete (SCC) and other Special types of Concretes, use of supplementary cementitious materials, use of alternative substitutes for cement and aggregates, the concrete mix design and manufacturing is becoming a complex process. The manual concrete making must be discouraged and ready mixed concrete manufacturing should be encouraged. Controlled use and compatibility of admixtures is also very important.

Ready mixed concrete can enhance the speed of construction and improve the quality of normal concrete, special and high performance concretes. The constituent materials of Ready Mixed Concrete (RMC), especially the fine aggregate, play a very important role for imparting better properties of concrete in its fresh and hardened state. River sand was the natural choice as fine aggregate for construction for many years. Due to the continuous mining of sand from river led to the depletion of river sand and it became a scarce material.

As an alternative to river sand, the RMC players are using quarry dust/CRF/Manufactured sand (M.Sand) which has been produced by crushing stone. The replacement levels vary from plant to plant and consultants' prescriptions. The quality and quantity of such sand replacements is questioned many times. More research is required to ascertain the durability of concrete when we use alternative fine aggregates. There is a strong need for detailed specifications and standards for different alternatives of sand.

Many RMC manufactures are now using manufactured sand and processed CRF's all over the world. The literature review and the experimental results shows that the quality of M.Sand is better than the river sand in many respects, such as cleanliness, grading, strength, angularity, flakiness, elongation etc. Design of RMC and its experimental investigation reveals that the use of M.Sand in RMC imparts better properties for RMC in its fresh state and hardened state. The study done by V. Syam Prakash [1] concludes that M.Sand is a suitable and viable substitute to river sand and could be effectively used in RMC which provides adequate strength and durability for the concrete. Some of the conclusions from the work done by V. Syam Prakash are presented below:

- M Sand is satisfying the requirements of fine aggregate such as strength, gradation, shape, angularity etc.
- The VSI technology adopted for the manufacture of M Sand assures the quality of fine aggregate.
- M.Sand can be produced to fall in the desired Zone according to our requirement. This can definitely ensure the quality of concrete.
- The mechanical properties of M.Sand depend on the source of its raw material. Hence selection of quarry is very important for obtaining quality fine aggregate.
- The workability of RMC has been maintained by the quality of M Sand used in this study. This enabled the transportability and pumpability.
- Compressive strength obtained for standard mortar cubes, nominal mix concrete and RMC indicates that the strength properties of M Sand are adequate.

- The requirement of cement has been observed to be very reasonable for all the mixes. The same content of cement was adequate for the same grade of mix with different admixtures.
- RMC prepared using all the three admixtures gave satisfactory results in terms of its workability and compressive strength

The numbers of RMC manufacturers are increasing to cater to the demands of the industry. Even though this is a welcome sign, there is no control on the quality of concrete produced from plants. Certification of all the RMC plants should be mandatory especially when we use alternative materials and admixtures. The quality and durability of concrete depends on the quality of all the ingredients and the manufacturing process. Considering the importance of the quality of concrete, RMCMA, QCI and BMTPC have come out with New Quality and Certification Standards for Ready Mixed Concrete Manufacturing.

The "Quality Team" of RMCMA has been working assiduously to evolve an indigenous framework for quality control and quality assurance of RMC. With the guidance of imminent National Experts, the Quality Team successfully developed an innovative framework of quality. The framework rests on two strong pillars best practices from advanced countries like the USA, UK, Canada, etc. that are suitable for Indian conditions and strict observance of provisions in the Indian codes like IS 4926:2003 (on RMC), IS 456:2000 (on plain and reinforced concrete), IS 383 (fine and coarse aggregates), IS 9103:1999 (chemical admixtures), etc.

After considerable deliberations and a number of revisions, RMCMA's Quality Team finalized two Quality Manuals, namely, QC Manual Part I and Part II. While the QC Manual Part I includes a comprehensive Check List essential for certification of ready-mixed concrete facilities, the QC Manual Part II provides guidelines for quality control and quality assurance of RMC. With a view to enhance credibility and customer confidence, it was unanimously decided to subject the RMC facilities to annual audits by external auditor. The credibility is further enhanced as the quality framework allows the customer to visit the RMC facility and cross check compliance with the Check List. The Quality manuals may be downloaded from: http://www.rmcmaindia.org/

With increased focus on infrastructure and housing activities, use of concrete in various forms is increasing day by day. For sustainability of RCC construction, proper quality of desired grade and optimum performance of concrete is of paramount importance. Ready Mixed Concrete that is batched in a controlled environment at a central plant instead of being mixed on the job site is always a better option. Starting from early nineties, RMC industry has grown from the second half of the nineties to the present state, when it has spread to the two and three tier cities also. With the rapid growth of the industry, the challenge of maintaining desired quality and standard of RMC plants have also increased. Realizing this challenge, Ready Mixed Concrete Plant Manufacture's Associations (RMCMA) took initiative to evolve a system of audit themselves and developed a detailed check list, based on international practices and relevant Indian Standards for audit.

To give the auditing an independent identity, RMCMA has now joined hands with Quality Council of India, who has taken responsibility to operate the certification of RMC plants. BMTPC has also joined hands with QCI & RMCMA to prepare the Criteria for Production Control of RMC Plant of Ready Mixed Concrete. The document Criteria of Production Control of Ready Mixed Concrete for RMC Capability Certificate has been prepared with wide consultation of members of Technical Committee representing user agencies, like CPWD, Airport Authority of India, Ministry of Road Transport & Highway, DMRC & National Highway Authority of India; R&D labs like NCCBM, CBRI; other experts and the industry represented by RMCMA; will form the basis of auditing of plants for the Certification Scheme.

Quality Council of India (QCI) has taken an initiative to establish an independent third party voluntary "RMC Plant Certification Scheme" in the country to assure quality in operations and processes of RMC Plants. This scheme was developed with the active participation and technical support from Ready Mixed Concrete Manufacturers' Association (RMCMA), a Mumbai based non-profit industry organization of leading Ready Mix Concrete (RMC) producers in India; Building Materials & Technology Promotion Council (BMTPC) under Ministry of Housing & Urban Poverty Alleviation, Government of India and various other stakeholders.

Ready Mix Concrete Plant Certification Scheme (RMCPCS)

In the era of huge infrastructure development in the country, the launch of this scheme will not only be very useful for the RMC manufacturing industry to benchmark itself with quality certifications but will also provide consumer the RMC produced in a quality certified RMC Plant. The RMC Plants Certification Scheme has two options for certification, one being 'RMC Capability Certification' and other being 'RMC 9000+ Capability Certification', the later ensuring compliance to the requirements of ISO 9001 also in addition to the QCI Scheme requirements.

The detailed Production Control Criteria for RMC has been established laying down the requirements on plant and equipment, key personnel, concrete mix design, production, testing facilities, control on quality of concrete ingredients, final product, delivery, control and maintenance of process control equipment etc. which the RMC Plant must comply in order to get certified under the scheme.

RMC Plants for obtaining above certification shall be certified by NABCB Accredited Certification Bodies complying with the requirements as specified under this scheme.

The following useful documents can be downloaded from: http://www.qcin.org/CAS/RMCPC/

1. Criteria for Production Control of RMC
2. Certification Process
3. Provisional Approval System for Certification Bodies
4. Application Form
5. List of Auditors
6. Approved Certification Body

Approved Certification Body for RMC Plant Certification Scheme

Certification No.	: RMCPCS - 001/13/002
Certification Body	: ICMQ Certification India Pvt. Ltd.
Contact Person	: Mr. Gopal Krishnan
Designation	: Management Representative
Address	: A-518, Sagar Tech Plaza, Andheri Kurla Rd Sakinaka Junction, Andheri (E) Mumbai - 400072
Tel.	: 022 - 4256 4356, 9322259803
Fax	: N.A.
Email	: r.gopalkrishnan@icmq.in; c.saccani@icmq.in

Certification No.	: RMCPCS - 002/13/003
Certification Body	: Bureau Veritas Certification (India) Pvt. Ltd.
Contact Person	: Mr. Rahul R Nayak
Designation	: Technical Manager
Address	: 6th Floor, Marwah Centre, Off. Saki- Vihar Road, Krishanlal Marwah Marg, Andheri (E), Mumbai - 400072
Tel.	: 022 - 66956300
Fax	: N.A.
Email	: rahul.nayak@in.bureauveritas.com

Acknowledgment:

- The above document is an extract from the Website's of RMCMA, QCI and BMTPC
- Mr. Vijay Kulkarni-Technical Adviser, QCI The man behind the quality schemes of RMC

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11. http://www.bmtpc.org/

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Ready Mixed Concrete Manufacturers' Association

RMCMA

NRMCA

TRAINING & CERTIFICATION COURSE

CONCRETE TECHNOLOGIST INDIA

Ready Mixed Concrete Manufacturers' Association (RMCMA) entered into a MoU with the National Ready Mixed Concrete Association (NRMCA), USA, for developing and offering Training and Certification Course for Concrete Technologists in India.

Termed as Concrete Technologist India (CTI) Course, the contents of the course are based on NRMCA's Concrete Technologist Level-II and III Programs. Modifications in the course content are done by RMCMA as required to suit Indian conditions and code requirements.

The first Pilot Training program in India was conducted in Mumbai from June 17 to 21, 2013. The pilot program was conducted by two experts from NRMCA, namely, Dr Colin Lobo and Dr Karthik Obla.

Participants in the CTI Pilot Training Program

CTI is a basic level training program in concrete technology and it is meant for all those involved in designing, specifying, producing, handling and testing batch plant concrete. The course is practice oriented and is tailor-made to suit RMC operations and includes the latest developments in concrete technology.

Main features of the CTI Program

- Full 4 days class-room training
- Printed Lecture notes on 20 topics in concrete technology with review questions
- Two-hour Examination on 5th day
- Examination assessment and Grading of participants done by NRMCA, USA
- Joint certificate issued by RMCMA & NRMCA
- Batch size of 25.

Who should register for CTI program?

- Technical and sales personnel from RMC plants
- Technical-support personnel from Contractors/Builders/Owners
- Technical-support personnel from Structural Consultants/Architects
- Project Management Consultants

Minimum qualification/experience for registration

Degree/diploma in civil engineering, science graduates with minimum experience of 3 years in RMC operations/concrete lab.

Future programs

Announcement of future programs will be made shortly.

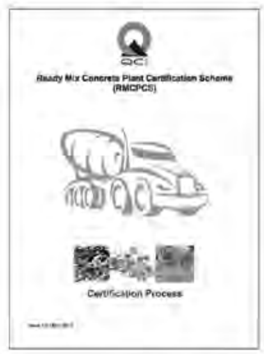
For more details contact: info@rmcmaindia.org

Ready Mixed Concrete Plant Certification Scheme

Ready Mixed Concrete Manufacturers' Association (RMCMA) has the distinction of being the pioneer in evolving, developing and implementing a Quality Scheme for Ready-Mixed Concrete. Aided by a team of National Experts, RMCMA prepared two Quality Manuals and the scheme was launched in December 2008. It was based on two strong pillars - best practices from advanced countries and strict adherence to BIS Standards. RMCMA operated the Quality Scheme through its independent group of auditors and till 2012 around 250 RMC plants in 50-plus locations in India were certified by the RMCMA for quality.

On realizing the need for up-gradation of its quality scheme RMCMA joined hands with the Quality Council of India (QCI). It was decided to evolve a more broad-based scheme with multi-stakeholder ownership, third-party independent character and bringing in international parity.

Quality Council of India took the initiative to establish three independent multi-stakeholder committees to spearhead preparation of the scheme documents. Besides RMCMA and Building Materials & Technology Promotion Council (BMTPC) under Ministry of Housing & Urban Poverty Alleviation, Government of India, the multi-stakeholder committees included participation from Central Government Ministries (e.g. Housing, MORT&H); CPWD; Central PSUs (e.g. NHAI, AAI); User bodies, (e.g. BAI, CFI); Professional bodies, (e.g. ICI, ICCE); Consultants, (e.g. Mahendra Raj, TCPL); and Certifying bodies, (e.g. BVCI, ICMQ). The committees finalized three manuals after rigorous review and discussion. The manuals conform to the requirements in relevant standards such as those of BIS, IRC, ISO, etc. These manuals shown below can be freely downloaded from QCI website http://qcin.org/CAS/RMCPC.



Download from http://qcin.org/CAS/RMCPC/

The new scheme was launched by QCI on May 17th 2013 at New Delhi and many RMC plants throughout the country are in the process of obtaining QCI certification.

The RMC Plants Certification Scheme has two options for certification, one being the 'RMC Capability Certification' and other 'RMC 9000' Capability Certification', the latter ensuring compliance to the requirements of ISO 9001 also in addition to the QCI Scheme requirements.

RMC Capability Certification

RMC 9000' Capability Certification

The certification is based on 6-monthly rigorous audit of RMC facility by an accredited certification body. RMC Capability Certification is plant-specific. RMC 9000' Capability Certification is optional, but for getting the same it is essential have RMC Capability Certification.

Benefits of QCI Scheme

- **For Owners & Specifiers (architects, consultants)**
  - Third-party quality assurance from an independent agency, based on well-defined quality norms evolved by experts
  - Reliable Tool for short-listing of concrete producers
- **For RMC/Concrete Producers**
  - Competitive advantage over non-certified producers
  - Top management gets audited data on their plants
- **Small Customer (e.g. individual house builder)**
  - Assurance on QA&QC of concrete, without employing experts
- **Concrete Industry**
  - Raise the industry standard and bring it on par with those from advanced countries.

Who should Apply for Certification?

The QCI certification is optional. However, looking at the benefits, specifiers and owners can make it mandatory for their projects/jobs. It is applicable to all commercial RMC plants as well as captive plants.

RMCMA strongly recommends to the adherence to the QCI Scheme and will ensure that all RMC plants belonging to its member companies will get certified under the new scheme within the next two years.

For more information contact: info@rmcmaindia.org

Metso Sand Solution

Source : RESULTS Minerals & Aggregates - METSO

STACY GOLDSWORTHY

Manufactured sand and its application is the leading growth area in aggregate for construction. Historically manufactured sand has been a by-product of the crushing and screening process. Today, due to environmental and urban expansion constraints, manufactured sand is becoming a sought after product. Manufactured sand can be used as product to control the cost and/or quality of aggregate production. It has been reported both in research and commercially that manufactured sand offers performance advantages to concrete, asphalt and mortar mixes. Specific characteristics of high quality product will improve the desired properties. Much of the hesitation in the use of manufactured sand for concrete mixes has been process-related. Production of manufactured sand has been more as a by-product rather then for an intended purpose. Value can be added to the whole operation by changing the focus of the crushing plant from producing crusher fines to producing high quality manufactured sand.

In recent years, much research has been carried out on the manufacturing of sand and we now have a better understanding of how sand characteristics affect concrete properties. Remarkable progress has also been achieved on the development of newequipment technologies and process control. The combination of both these factors have contributed decisively to the creation of technology and total dominium of process capable to generate high quality manufactured sand, taking in account the resource rock characteristics and demand for high quality manufactured sand.

Application of manufactured sand

The use of manufactured sand is increasing year on year. Its continued and expanded use will only come from improved knowledge about its utilisation and the implementation of process technology that allows successful use. Optimisation of process to suit source rock characteristics is the key part of the design process. The use of aggregate in concrete is to fill voids. This must be done in such a way that the concrete will have the right performance attributes in the field, whether this is workability, strength, pumpability or finishability. Figure 1 shows the main constituents of concrete, coarse aggregate, sand and filler usually in the form of cement. When produced through the correct process manufactured sand will improve the quality of concrete. Field experience has shown that source rock properties have a significant effect on performance. Finer grained rock with intrinsic high strength tends to produce manufactured sands that are angular and have a deficiency in particle sizes in the 0.6 to 0.15mm size range (for example, basalt). Crystalline rocks tend to produce a sand that has more cubical particles and all particle sizes are well represented (for example, granite). A significant barrier to widespread use in concrete is the content of filler (minus 0.075mm material fraction). Source rock properties have a large influence on the production of filler. So, source rock properties investigation is a mandatory step to produce manufactured sand with suitable filler content.

Traditional concrete manufacture has not employed large quantities of manufactured sand. Excess amounts are classified and can either end up as slimes in sedimentation ponds or increasingly the use of air classification is employed to classify filler. Rheological properties of manufactured sand J. Cleland first introduced the Sand Flow Cone in the 1968 New Zealand Standards bulletin. His thinking was that the rheological properties of sand were more important than the particle size distribution. Through our work with manufactured sand we have found that his assumptions were largely correct. What is important is that all particle sizes are well represented to ensure that suitable concrete properties are achieved. The effect of shape is important to the rheological properties of sand. Sands that are of poor shape or are too angular increase internal friction, which leads to increased water demand. An excessive increase in water demand leads to increased production costs. All things being equal, increased water demand for a given workability increases the cement dosage required to achieve a given strength, hence the reluctance for concrete producers to use manufactured sand. In the past poor quality manufactured sand has pushed up water demand. A high quality manufactured sand produced by an optimized process will produce better performing sand. While water demand is higher than an equivalent natural sand, there are other factors that have influenced performance.

Process

Correct process for the production of manufactured sand is key to producing an aggregate of sufficient quality for concrete production. The process used must match the properties of the source rock. If the fragmentation of the source rock is such that the sand produced meets gradation requirements then the process can be simplified. In the case of source rocks with higher intrinsic strength, the process needs to be refined to produce the required shape and gradation requirements.

To determine the process requirements a full understanding of the source properties must be gained. Usual source property testing and petrographic analysis will give insights to the possible fragmentation. From this information the right crushing and classification equipment can be selected to meet the market needs. Selection of the crusher for manufactured sand production depends on source rock properties such as fragmentation pattern and hardness and the application to which the sand will be applied. Two crushers have proven capability to produce high quality sand for concrete and asphalt - autogenous VSIs and new generation high speed cone crushers. Metso Minerals owns global leading technology in both crusher types through Barmac B-Series VSIs and HP cones. The selection of a crushing circuit should be such that the quality of the source rock is taken into account. We have found the energy input is directly proportional to the strength of the rock. Higher strength rock requires more energy input to create surface area. The consequence is the production of amounts of filler too high for normal concrete production or which may be out of specification. For successful use the filler must to classified. A typical process flow can be seen in Figure 2, where a VSI, high frequency screen and air classifier have been installed to produce high quality fine aggregate products.

Filler classification operating costs

Filler must be dried for use in asphalt and specialty fine sand such as plastering sand. In the case of asphalt, drying is required to allow bitumen to coat the surface of the stone. For fine sands drying is required to meet the market expectation. Many of these products are bagged and not sold in bulk. For most dryers the average energy requirement for 1% reduction in moisture is seven litres of diesel. To achieve a cost saving in the application of air classification, in the ideal environment, the final products should be kept as dry as possible to reduce the cost associated with drying. This is especially so where fine sand products are packaged for market.

Wet processing leaves free water on the surface of aggregate. Depending on aggregate particle size, the free water contained can be upwards of 10%. Finer particles have the capacity to hold more water due to a higher surface area that greatly increases drying costs.

Quality control tools

The need for quality control is paramount in ensuring a consistent end product. In the words of the late, great, W. Deming: “Quality is the elimination of variation”. Never was a truer word said. Quality control for aggregate production can only be achieved by adding process and process control. Adding process adds cents to aggregate production, while the resulting product reduces the total cost of production by dollars. The common attitude of ready-mix and asphalt producers is: “We don’t care what you give us, just make sure it is always the same”. While this may be good for some producers, those with a drive to improve quality will look for high quality solutions. Defect rates are a major cost to both concrete and asphalt producers. Defects in the final product are a result of variations in the production process. If the variation is noted before or during the production process then some allowance can be made to mitigate its effect. In most cases the quality issue that will cause the defect is not noted and results in end product failure. This adds significant cost to the process. Once aggregate reports to the stockpile it is subjected to the elements and to handling. Depending on the aggregate this may alter the quality of the aggregate. Breakdown of the aggregate, contamination and variations in water content are common problems having an effect on the performance of the aggregate in end products such as asphalt and concrete. To compensate, the end customer adds a little bit more cement to ensure their products meet the quality requirements. This comes at a cost to the total production cost. If the aggregate reports directly to the final product then this change in quality does not occur.

Market demands cannot be this accurately determined for plant production to be matched. Customers who see the value of having higher quality control over aggregate input are moving to increasing process and process control. Some customers have seen the need to control what is being produced from the plant. All aggregates report to silos so they can report directly to the asphalt plant. This type of customer has ambitions on becoming a supplier of higher quality manufactured sand to both ready mix and precast producers. The quality control exercised over the products will ensure higher quality product and higher market value. Filler classification offers a means of effective control over the gradation of sand. For both asphalt and concrete the sand fraction has the greatest influence on performance. To control gradation through improved process will add value to the product and the final aggregate quality.

Metso Sand Solution

Metso Minerals has seen the need to develop systems and process to assist our customers to find a market for high quality manufactured sand. To this end a work group has been assembled to bring together our wide experience in sand production. The solutions we are offering have been optimised from customer feedback and field success. The Metso Minerals Sand Solution equipment offering has been rationalised based on what works. Efficient crushing and screening systems are utilised to reduce production costs and to offer consistent product quality. This allows our customers to drive down total production costs while maintaining high product yields.

Conclusion Manufactured sand can be successfully used in concrete. Its use is dependant on achieving the right gradation and particle shape to limit water demand. If these properties are produced to provide a high quality sand then performance in the hardened state can be better than that of natural sand. The use of air classification to remove filler from a manufactured sand has allowed control to be given to the sand manufacture process. Sand produced through a crushing and screening plant can have the filler removed to be utilised as a filler in concrete mixes. A holistic view of concrete production needs to be taken by the aggregate industry. Producing aggregate of a higher quality will reduce the overall production cost. The improvement in quality not only affects production costs but failure in the field.

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Industrial Solid Waste

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INTRODUCTION

Environmental pollution is the major problem associated with rapid industrialisation, urbanisation and rise in living standards of people. For developing countries, industrialisation was must and still this activity very much demands to build self reliant and in uplifting nation's economy. However, industrialization on the other hand has also caused serious problems relating to environmental pollution. Therefore, wastes seem to be a by-product of growth. Therefore, efforts are to be made for controlling pollution arising out of the disposal of wastes by conversion of these unwanted wastes into utilisable raw materials for various beneficial uses. The problems relating to disposal of industrial solid waste are associated with lack of infrastructural facilities and negligence of industries to take proper safeguards.

Industries generating solid waste have to manage such waste by themselves and are required to seek consent/ authorisations from respective State Pollution Control Boards (SPCBs) under relevant rules. However, through joint efforts of SPCBs, local bodies and the industries, a mechanism could be evolved for better management. In recent years availability of raw material for infrastructure projects is a great challenge in Karnataka. Karnataka State Pollution Control Board is exploring all possibilities and co-coordinating with various stakeholder for utilizing solid waste as an alternative raw material.

THE PROBLEMS

Assessment of industrial solid waste management problem greatly varies depending on the nature of the industry, their location and mode of disposal of waste. Further, for arriving at an appropriate solution for better management of industrial solid waste, assessment of nature of waste generated is also essential.

Industries are required to collect and dispose of their waste at specific disposal sites and such collection, treatment and disposal is required to be monitored by the concerned State Pollution Control Board (SPCB) or Pollution Control Committee (PCC) in Union Territory. The following problems are generally encountered in cities and towns while dealing with industrial solid waste

- There are no specific disposal sites where industries can dispose their waste;
- Mostly, industries generating solid waste in city and town limits are of small scale nature and even do not seek consents of SPCBs/PCCs ;
- Industries are located in non-conforming areas and as a result they cause water and air pollution problems besides disposing solid waste.
- Industrial estates located in city limits do not have adequate facilities so that industries can organise their collection, treatment and disposal of liquid and solid waste;
- There is no regular interaction between urban local bodies and SPCBs/PCCs to deal such issues relating to treatment and disposal of waste and issuance of licenses in non-conforming areas.

INDUSTRIAL SOLID WASTE

The major generators of industrial solid wastes are the thermal power plants producing coal ash, the integrated Iron and Steel mills producing blast furnace slag and steel melting slag, non-ferrous industries like aluminum, zinc and copper producing red mud and tailings, sugar industries generating press mud, pulp and paper industries producing lime and fertilizer and allied industries producing gypsum.

Table: 6.1 Source and Quantum of generation of some major industrial waste

S.No	Name	Quantity (million tonnes per annum)	Source/Origin
1.	Steel and Blast furnace	35.0	Conversion of pig iron to steel and manufacture of Iron
2.	Brine mud	0.02	Caustic soda industry
3.	Copper slag	0.0164	By product from smelting of copper
4.	Fly ash	70.0	Coal based thermal power plants
5.	Kiln dust	1.6	Cement plants
6.	Lime sludge	3.0	Sugar, paper, fertilizer tanneries, soda ash, calcium carbide industries
7.	Mica scraper waste	0.005	Mica mining areas
8.	Phosphogypsum	4.5	Phosphoric acid plant, Ammonium phosphate
9.	Red mud/ Bauxite	3.0	Mining and extraction of alumina from Bauxite
10.	Coal washery dust	3.0	Coal mines
11.	Iron tailing	11.25	Iron Ore
12.	Lime stone wastes	50.0	Lime stone quarry

(Source : National Waste Management Council-Ministry of Environment & Forests-1990/1999)

DESCRIPTION OF IMPORTANT INDUSTRIAL SOLID WASTE

Coal Ash

In general, a 1,000 MW station using coal of 3,500 kilo calories per kg and ash content in the range of 40-50 per cent would need about 500 hectares for disposal of fly ash for about 30 years' operation. It is, therefore, necessary that fly ash should be utilised wherever possible to minimize environmental degradation. The thermal power plant should take into account the capital and operation/maintenance cost of fly ash disposal system as well as the associated environmental protection cost, vis-a-vis dry system of collection and its utilisation by the thermal power plant or other industry, in evaluating the feasibility of such system.

The research and development carried out in India for utilisation of fly ash for making building materials has proved that fly ash can be successfully utilised for production of bricks, cement and other building materials. Indigenous technology for construction of building materials utilising fly ash is available and are being practised in a few industries. However, large scale utilisation is yet to take off. Even if the full potential of fly ash utilisation through manufacture of fly ash bricks and blocks is explored, the quantity of fly ash produced by the thermal power plants are so huge that major portion of it will still remain unutilised. Hence, there is a need to evolve strategies and plans for safe and environmentally sound method of disposal.

Integrated Iron & Steel Plant Slag

The Blast Furnace (BF) and Steel Melting Shop (SMS) slags in integrated iron and steel plants are at present dumped in the surrounding areas of the steel plants making hillocks encroaching on the agricultural land. Although, the BF slag has potential for conversion into granulated slag, which is a useful raw material in cement manufacturing, it is yet to be practised in a big way. Even the use of slag as road subgrade or land-filling is also very limited.

Phosphogypsum

Phosphogypsum is the waste generated from the phosphoric acid, ammonium phospate and hydrofluoric acid plants. This is very useful as a building material. At present very little attention has been paid to it s utilisation in making cement, gypsum board, partition panel, ceiling tiles, artificial marble, fiber boards etc.

Red Mud

Red mud as solid waste is generated in non-ferrous metal extraction industries like aluminum and copper. The red mud at present is disposed in tailing ponds for settling, which more often than not finds its course into the rivers, especially during monsoon. However, red mud has recently been successfully tried and a plant has been set up in the country for making corrugated sheets. Demand for such sheet should be popularised and encouraged for use. This may replace asbestos which is imported and also banned in developed countries for its hazardous effect. Attempts are also made to manufacture polymer and natural fibres composite panel doors from red mud.

Lime Mud

Lime sludge, also known as lime mud, is generated in pulp & paper mills which is not recovered for reclamation of calcium oxide for use except in the large mills. The lime mud disposal by dumping into low-lying areas or into water courses directly or as run-off during monsoon is not only creating serious pollution problem but also wasting the valuable non-renewable resources. The reasons for not reclaiming the calcium oxide in the sludge after recalcination is that it contains high amount of silica. Although a few technologies have been developed to desilicate black liquor before burning, none of the mills in the country are adopting desilication technology.

Waste Sludge and Residues

Treatment of industrial wastes/effluents results in generation of waste sludge/residues which, if not properly disposed, may cause ground and surface water pollution.

Potential Reuse of Solid Wastes

Research and Development (R&D) studies conducted by the R&D Institutions like Central Building Research Institute, Roorkee (CBRI) and the National Council for Building Research, Ballabgarh (NCBR) reveal that the aforesaid solid wastes has a very good potential to be utilised in the manufacture of various building materials.

WASTE MANAGEMENT APPROACH

A two-tier approach should be thought of for waste management, e.g., (a) prevention & (b) control of environmental pollution. Prevention aims at minimisation of industrial wastes at source, while the latter stresses on treatment and disposal of wastes. .

Prevention-A Waste Minimisation Approach

Reduction and recycling of wastes are inevitably site/plant specific. Generally, waste minimisation techniques can be grouped into four major categories which are applicable for hazardous as well as non-hazardous wastes. These groups are as follows;

Inventory Management and Improved Operations

- Inventorisation and tracing of all raw materials ;
- Purchasing of fewer toxic and more non-toxic production materials ;
- Implementation of employees' training and management feedback ; and
- Improving material receiving, storage, and handling practices.

Modification of Equipment

- Installation of equipment that produce minimal or no wastes ;
- Modification of equipment to enhance recovery or recycling options;

- Redesigning of equipment or production lines to produce less waste ;
- Improving operating efficiency of equipment ; and
- Maintaining strict preventive maintenance programme.

Production Process Changes

- Substitution of non-hazardous for hazardous raw materials ;
- Segregation of wastes by type for recovery ;
- Elimination of sources of leaks and spills ;
- Separation of hazardous from non-hazardous wastes ;
- Redesigning or reformulation for products to be less hazardous; and
- Optimisation of reactions and raw material use.

Recycling and Reuse

- Installation of closed-loop systems ;
- Recycling off site for use ; and
- Exchange of wastes

Waste Management at Source

A specific example worth-mentioning in this context is removal of fly ash through coal beneficiation process at the mine head in view of high ash content. It is evident that the larger the volume of waste and the longer the distance of transportation of raw material (coal), the bigger will be the economic benefit in favour of coal beneficiation instead of carrying the filthy fly ash. However, benefit-cost analyses have to be made before taking appropriate decision.

It is possible to cut down waste generation at source by simple, inexpensive measures modifying production processes, through changes in raw materials/product design and by employing recovery/ recycling and reuse techniques

To avoid treatment through utilisation of waste, it is important from the environmental pollution view point as well as for the benefit of entrepreneurs to recycle and reuse the wastes generated by adoption of certain process change or by use of low/no-waste generation technology.

Waste minimisation can be practised at various places in the industrial processes. Waste minimisation requires careful planning, creative problem evolving, changing in attitude, some times capital investment, and most important a real commitment. More often than not, investment on waste minimisation and recovery pays off tangibly within a short time. Such studies have been conducted and results are provided in Table 1.

TABLE: 1

Investment on Waste Minimisation and Recovery

Industry	Total waste-water flow(Cubic metres per day)	Total cost of plant (Rs. in thousand)	Net annual recovery (Rs. in thousand)	Investment pay back period (yrs)	Remarks
Textile Industry	6,450	4,625	4,375	1.05	Recycle in process house
Alcohol Industry	1,725	2,250	975	2.30	Reuse of energy in process house
Food Processing	1,460	10,500	4,250	2.47	Recycling for irrigation/ process house and reuse of energy
Viscose Rayon	4,500	200	36	5.5	Recovery and reuse of zinc. Foreign exchange saving.
Cement Industry (1200 t.p.d. production capacity)	-	3,44,000	2,24,000	1.50	Recovery & reuse of cement and clinker dust

(Source : Industrial Waste Management, NWMC, 1990)

The initial investment for a pollution prevention project may be higher in some cases than the cost of installing conventional pollution control equipment. However, the annual operation and maintenance cost of the removal will almost always make the total cost of treatment higher than the total cost of preventive measures at sources. However, treatment and disposal of residual waste even after taking preventive measures should be given due consideration.

AREA OF APPLICATION OF SOME IMPORTANT INDUSTRIAL WASTES

S.No.	Waste	Areas of Application
1.	Flyash	• Cement
		• Raw material in Ordinary Portland Cement(OPC)
		• manufacture
		• Manufacture of oilwell cement.
		• Making sintered flyash light-weight aggregates.
		• Cement/silicate bonded flyash/clay binding bricks and insulating bricks.
		• Cellular concrete bricks and blocks, lime and cement fly ash concrete.
		• Precast flyash concrete building units.
		• Structural fill for roads, construction on sites,
		• Land reclamation etc.
		• As filler in mines, in bituminous concrete
		• As plasticiser
		• As water reducer in concrete and sulphate resisting concrete
		• Amendment and stabilisation of soil.

2.	Blast Furnace Slags	• Manufacture of slag cement, super sulphated cement, metallurgical cement.
		• Non-portland cement
		• ii.Making expansive cement, oilwell, coloured cement and high early-strength cement.
		• In refractory and in ceramic as sital
		• As a structural fill (air-cooled slag)
		• As aggregates in concrete.
3.	Ferro-alloy and other metallurgical slags.	• As structural fill
		• In making pozzolana metallurgical cement
4.	By product gypsum	• In making of gypsum plaster, plaster boards and slotted tiles
		• As set controller in the manufacture of portland cement
		• In the manufacture of expensive or non-shrinking
		• cement, super sulphated and anhydrite cement
		• As mineraliser
		• Simultaneous manufacture of cement and sulphuric acid
5.	Lime sludge (phos-phochalk, paper and sugar sludges)	• As a sweetener for lime in cement manufacture
		• Manufacture of lime pozzolana bricks/ binders
		• For recycing in parent industry
		• Manufacture of building lime
		• Manufacture of masonry cement
6.	Chromium sludge	• As a raw material component in cement manufacture
		• Manufacture of coloured cement as a chromium-bearing material
7.	Red mud	• As a corrective material
		• As a binder
		• Making construction blocks
		• As a cellular concrete additive
		• Coloured composition for concrete
		• Making heavy clay products and red mud bricks
		• In the formation of aggregate
		• In making floor and all tiles
		• Red mud polymer door
8.	Pulp & Paper	• Lignin

(Source : Industrial Waste Management, NWMC, 1990)

CURRENT PRACTICE OF INDUSTRIAL SOLID WASTE MANAGEMENT

Collection and Transport of Wastes

Manual handling of industrial waste is the usual practice in developing countries; there are very few mechanical aids for waste management. Wastes are shovelled by hand into storage containers and loaded manually into lorries. The people undertaking salvaging do so mainly by hand, picking out useful items, usually not even wearing gloves. Although there may not be a health risk in handling clean waste paper, people handling or salvaging waste without protective clothing are at risk when waste is mixed with chemicals. Apart from the likelihood of cuts caused by broken glass or sharp metals, sorting through waste contaminated with hazardous chemical materials could cause skin burns, excessive lacrimation, or even loss of consciousness; chronic hazards include respiratory problems from dust inhalation, and potential carcinogenicity from toxic chemicals present in discarded containers or surface deposits in other waste. Personnel handling waste from tanneries or hide processors may also be exposed to such diseases as anthrax. Necessary precautions will reduce and minimise hazards associated with manual handling of industrial wastes. Personnel handling hazardous wastes should wear appropriate protective clothing. Mechanical methods for handling waste should be adopted wherever possible, and people should be educated about the dangers of manual handling of hazardous waste.

Storage & Transportation

The storage of industrial solid waste is often one of the most neglected areas of operation of a firm. Very little attention is paid to proper storage and heaps of mixed waste piled against a wall or on open ground are a common sight in many factories. Concrete bays or disused drums are also often used for storage. Whereas the sludges originating from holding tanks or interceptors do not present storage problems as no separate sludge storage is required, because the sludge is retained in the tank until sufficient quantities are collected. Waste is rarely covered, protected from vermin or pretreated in any manner. There are no restrictions on access and employees are often encouraged to sort out through such wastes and take away any useful material or articles they find. Waste is regarded as an unwanted product by firms and very often no senior person is assigned for its control. Transportation of industrial waste in metropolitan areas of developing countries is generally not by purpose-built vehicles such as skip-carrying lorries, but by open trucks. The wastes are not covered during transportation. It is typical for a firm not to have any standing arrangements with one contractor, but to allow collection by whoever is the contractor quoting lowest rates. It is rare for special arrangements to be made for hazardous wastes; they are usually collected together with the other wastes. Contractors who carry hazardous waste do not need to be licensed, and consequently, there is little control over either the types of firms engaged in carrying hazardous waste or the vehicles used. Drivers are not given a list of precautions to be taken; there is no manifest or labeling system of wastes during transport. Fly-tipping is often prevalent and wastes are often taken to disposal sites inappropriate for the type of waste concerned.

Disposal of Industrial Solid Waste

Industrial waste, whilst presenting the same disposal problems as domestic waste, also contains hazardous waste, thereby exacerbating the difficulties of disposal. Fortunately, the types of industrial wastes generated in a municipal area of a developing country are such that there are not usually large quantities of particularly hazardous wastes for disposal. In the past there has been little control over the disposal of industrial wastes; indeed, it has only been during the last decade that even developed countries have brought in legislation to curb the uncontrolled and environmentally unacceptable practices that were widespread. Without such legislation disposal is almost always by uncontrolled landfill at sites which often pose a threat of water pollution due to leachates.

HEALTH CONSEQUENCES OF POOR INDUSTRIAL WASTE DISPOSAL

The solid waste generated from industrial sources contains a large number of chemicals, some of which are toxic. The waste is considered toxic, if the concentration of the ingredients exceeds a specified value. Although the levels of some ingredients may occasionally exceed the permissible level, the waste as such is considered to be toxic only if the average value of ingredients exceeds the toxicity level. Various criteria and tests have been devised by different agencies to determine the toxicity of a given substance. It is necessary to know the properties of the waste so as to assess whether its uncontrolled release to the environment would lead to toxic effects on humans or other living organism in ecosystem. This evaluation is carried out using criteria such as toxicity, phytotoxicity, genetic activity and bio-concentration. The potential toxic effects also depend on quantity of the toxic constituents. Substances are classified as hazardous or otherwise depending on the dose, exposure, and duration of exposure. For a chemical to affect human health it must come in contact with or enter the human body. There are several ways in which this can happen.

Skin contact:

Chemicals that cause dermatitis usually do so through direct contact with skin. Some chemicals like corrosive acids can damage the skin by a single contact while others, like organic solvent, may cause damage by repeated exposure.

Inhalation :

Inhalation is the most common source of workplace exposure to chemicals and the most difficult to control. Air pollutants can directly damage respiratory tract or gets absorbed through lung and cause system/systemic effects. An adult male will breathe about 10 cubic meters of air during a normal working day.

Ingestion :

Ground water and sub soil water contamination from leachates from refuse dumps and poorly managed landfill sites can result in ingestion of toxic chemicals by population groups who live far away from the factory sites and decades after the garbage has been dumped.

There are very few studies conducted in India on specific health problems resulting from accidental exposure to toxic industrial solid waste. There had been reports that sacks, cardboard cartons and paper envelopes contaminated with chemicals packed in them were burnt and the irritating fumes from these caused respiratory problems. There had also been reports of skin or respiratory irritation following exposure to corrosives chemicals. There has been no efforts to systematically investigate and obtain reliable epidemiological data on health consequences of exposure to hazardous industrial wastes in different States.

Wastes from slaughter house is potentially infectious. All precautions to ensure that potential pathogens to not gain a foot hold in the workers in the slaughter house and in the general population, have to be taken during collection, storage and disposal of the slaughter house waste.

Wastes from non hazardous industries can at times produce health problems, not only among the workers and handlers of waste, but also among general population. One example of this category is the cotton dust. Cotton waste are generally non hazardous; however they may, in susceptible individuals provoke respiratory allergic reactions; allergy may be due to inhalation of dust containing cotton wastes or fungus or other contaminants in the waste dust.

COLLECTION, STORAGE TREATMENT & DISPOSAL OF WASTES

Waste Segregation

Many wastes are mixtures of hazardous and non-hazardous wastes. Much of their contents may even be water. By segregating key toxic constituents, isolating liquid fraction, keeping hazardous streams away from non-hazardous wastes, generator can save substantial amounts of money on disposal or find new opportunities for recycling and reuse of wastes. The Ministry of Environment, Government of India, had identified toxicity of different chemicals, through the 'Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989' in exercise of power conferred by Section 6, 8 and 25 of Environment Protection (E.P). Act, 1986, and had notified mandatory requirements for its management. In India quantum of generation of wastes (solid/liquid and hazardous/non-hazardous) for different industry has not been detailed, which is necessary for wastes exchange system or for adopting treatment/ disposal alternatives for different wastes segregated.

Collection, Storage and Transport

The unsatisfactory state of storage of hazardous wastes can be remedied to a large degree by such low-cost measures as restricting access, fencing off the storage area to minimise any wind-blown nuisance, providing separate covered storage for putrifiable of hazardous wastes, and ensuring regular and frequent collection. There are certain measures a municipal authority can take to control the transportation of industrial wastes, even if it does not want to become actually involved itself. For instance, contractors should be licensed after ensuring that they are technically competent and environmentally aware and should be allowed to handle industrial wastes. Labeling and coding of hazardous waste load can be made mandatory so that in the event of an accident, the emergency services know how to handle a spillage. Municipal authorities can be given the responsibility to monitor the contractors to minimise cases of fly-tipping and ensure that industrial wastes are disposed at the appropriate sites. If a municipal authority can also collect industrial waste; industries must pay the charge which will be based on the quantity and nature of the waste. This might minimise the quantity of waste produced by industry and at the same time the programme will become financially viable and self sustaining. The principle 'the polluter pays' should be adhered to in all such cases.

Combined Treatment Facilities

Small-scale industries, which contribute about more than half of the total production, also generate huge quantity of wastes. The small-scale industries are not in a position to treat their solid wastes or liquid effluent because of space, technical know-how and financial constraints. It is, therefore, deemed that in a cluster of small-scale industries the different wastes are characterized, identified, quantified and stored for treatment through a combination of recycling, recovery and reuse of resources such as, raw material, bio-gas, steam and manure, besides providing an efficient service facility, to make the system less expensive. The combined effluent treatment plants (CETP) are to be operated by the local bodies, where the cost of construction, operation and maintenance need to be shared by individual industries depending upon the quality and quantity of wastes generated. However, such common treatment facility may require pre-treatment at individual industry to the extent specified by the State Pollution Control Board. With regard to availability of wastes along with their identification, quantum of waste generated should also be ascertained so that technology development/adoption can be considered on economic grounds for a small-scale or organised sector of industry. If economics justify movement of wastes over longer distances for a centralised plant, specific subsidies for storage, collection and transportation could be considered. CETPs are being successfully operated in Bangalore. Kolar and Bidar and such facilities should be promoted in other Districts.

Small scale industries having waste characteristics similar to those of near by large industry having waste treatment facilities can take help in treating their wastes on payment basis.

Disposal Methods

Depending upon the characteristics of the wastes, different types of disposal methods can be used for hazardous and non-hazardous industrial wastes. The most predominant and widely practised methods for wastes disposal are : (a) Landfill, (b) Incineration and (c) Composting.

For thousands of years, man has disposed the waste products in a variety of ways, the disposal method might reflect convenience, expedience, expense, or best available technology. There were no major ecological or health hazards associated with these practices until the last century. Explosive increase in the amount of chemical waste produced and the indiscriminate dumping of hazardous industrial waste in the last few decades has created health and ecological crisis in many areas

of the world. In many instances, leachate from the wastes dumped by one generation haunts the later generation in the form of ground water and subsoil water contamination. The recent discovery of volatile organic chemicals from landfills and industrial disposal ponds is disturbing because many of these chemicals are known or suspected carcinogens and are not removed easily by natural geochemical processes. The risk of the contamination of groundwater supplies due to leachates from landfills depends on several factors; toxicity and volume of the contaminant generated at each site, the nature of the geologic medium underlying the site, and the hydrologic conditions dominant in the area.

In the past, the least expensive and most widely used waste management option for both municipal and industrial waste has been the sanitary landfill, where wastes are compacted and covered with earth. In any geographic area other than arid zones, the fill is subjected to percolating rainwater or snowmelt which eventually flows out from the bottom of the landfill site and moves into the local groundwater system. Leachate is a liquid that is formed as infiltrating water migrates through the waste material extracting water-soluble compounds and particulate matter. The mass of leachate is directly related to precipitation, assuming the waste lies above the water table. Much of the annual precipitation, including snowmelt is removed by surface run off and evaporation; it is only the remainder that is available to form leachate. Since the landfill covers to a large extent and controls leachate generation, it is exceedingly important that the cover be properly designed, maintained and monitored in order to minimise leachate production. Fortunately, many substances are removed from the leachate as it filters through the unsaturated zones, but leachate may pollute groundwater and even streams.

These leachates, can contain large amount of inorganic and organic contaminants. At some sites, the leachate is collected and treated. But even in the best engineered sites, some leachate escapes into the groundwater system because no permanent engineering solution has been found to isolate the leachate completely from the groundwater.

It is now recognised that the interaction between leachate and soil are actually very complex and depend both on the nature of soil and on the leachate. When leachate percolates through solid wastes that are undergoing decomposition, both biological materials and chemical constituents are picked up. Recent research in the United Kingdom (U.K) has, however, shown that chemical and biological phenomena in landfill such as microbiological process; neutralisation; precipitation and complexion; oxidation and reduction; volatilisation; adsorption reduce the quantity and quality of polluting leachate from landfill site and achieve some degree of on-site treatment or immobilisation. In spite of all these, the leachate often pose severe disposal problem at a landfill site. Two of the most economic but efficacious purification methods are spraying over grassland or percolation through an aerobic bed of sand or gravel.

In general, it has been found that the quantity of leachate is a direct function of the amount of external water entering the landfill. In fact, if a landfill is constructed properly, the production of measurable quantities of leachate can be eliminated. When sewage sludge is to be added to the solid wastes to increase the amount of methane produced, leachate control facilities must be provided. In some cases leachate treatment facilities may also be required. The pollution of static water ditches, rivers or the sea can occur when a sanitary landfill adjoins a body of water. The normal source of the leachate causing this pollution is rain falling on the surface of the fill, percolating through it, and passing over an impermeable base to water at a lower level. The quantity of leachate can be substantially increased when upland water drains across the site of the landfill, but the worst case is when a stream crosses the site. The solutions to these problems lie in appropriate site engineering such as:

(i) diversion or culverting of all water courses which flow across the site,

(ii) diversion of upland water by means of drainage ditches along appropriate contours,

(iii) containment of leachate arising from precipitation by the construction of an impermeable barrier where necessary, such as a clay embankment adjoining a river,

(iv) grading the final level of the site so that part of precipitation is drained across surface, thereby reducing percolation below the level needed to produce a leachate.

Works of this nature will obviously add to the cost of a sanitary landfill project. However, when capital expenditure is spread over the life of the project, the cost/ton of waste disposed might be less than for any alternative method of disposal. Furthermore, some of these forms of expenditure, such as culverts or river walls, represent capital assets of continuing value when the reclaimed land is handed over for its final use, perhaps for agriculture or recreation.

Incineration of hazardous industrial waste has been advocated in developed countries. Guidelines for safe incineration of hazardous chemical waste have been drawn up by United States Environmental Protection Agency. Incineration of hazardous waste is a process requiring sophisticated expensive incinerators and a high degree of technological expertise for satisfactory operation. The capital cost of incinerator is high, especially if it is intended for hazardous wastes and gas scrubbing equipment is required. Some wastes such as oils and organic solvents can be readily treated by incineration. If financial constraints come in the way of purchasing sophisticated incinerators then the utilisation of open pit incinerator under careful technical supervision can be considered as an option.

Landfill

The owner or operator of a facility must follow the design and operating criteria stipulated by the regulatory agencies. However, depending upon the characteristics of the waste, the landfill system with leachate collection system has to be designed with necessary facility for ground water quality monitoring.

V. Anand
Environmental Officer
Karnataka State Pollution Control Board
Bangalore

Initiatives taken in Karnataka by State Pollution Control Board

V. Anand, KSPCB

Karnataka is one amongst the industrially developed States in the Country. The State Government has introduced Industrial Policy 2006-11 with an aim to increase the growth of GDP, strengthen manufacturing industries, increase share of exports from Karnataka, to generate additional employment of atleast 10 lakh persons in the manufacturing and service sectors, reduce regional imbalance and ultimately aim at overall socio-economic development of the State.

To harness the local natural resources and also to optimize its value addition, following sector specific industrial zones is being developed:

- Steel : covering Bellary, Koppal, Bagalkot, Haveri,Gadag & Raichur Districts
- Cement : covering Gulbarga, Bagalkot, Chitradurga, Belgaum and other Districts.
- Food Processing : covering Bangalore Rural, Kolar, Belgaum, Gadag, Koppal, Shimoga, Bagalkot, Bijapur,Davangere, Mandya and Dharwad Districts.
- IT / BT : covering Mysore, Mangalore, Hubli-Dharwad, Belgaum, Shimoga, Gulbarga, Kolar and Mandya Districts
- Automobile : covering Ramanagara, Shimoga Dharwad and Kolar Districts.
- Readymade garments : covering Bangalore Rural, Tumkur, Kolar, Mandya, Belgaum, Bidar, Dharwad and other Districts.
- Sugar and co-gen, power: covering Bidar, Belgaum, Bagalkot, Shimoga and Mandya Districts.
- Pharmaceutical/Bio-Technology: covering Bangalore, Mysore and Hassan Districts.
- Power Generation: covering Raichur, Bellary, and Bijapur & Chitradurga Districts.
- Media & Entertainment : Bangalore (R) and Ramanagara

A foundry park is planned to be established in Mache Village of Belgaum district in addition to a spice park in Byadagi of Haveri district. An auto park is also proposed to be established in Basava Kalyan, Bidar district. It is proposed to develop a residential workshop and infrastructure facilities for the artisans engaged in the preparation of silver ornaments in Mangoor village of Chikkodi taluk in Belgaum district

Karnataka is the 3rd largest producer of steel in India with a current production level of 10.7 million tons/annum. Generally a blast furnace operates on a continues ba---and produces approximately 250-300 kg of slag per tone of iron produced. Major Pig iron produces are KFIL, KSL, SLR mettalies and JSW. The total iron producing capacity is about 114,00,000 TPA.

In Indalco, Belgaum after recovery of aluminum from the Bauxite, the red mud Of quantity 550,000 MT/A is generated. It is stored over a layer area creating an artificial hillock, composition of the red and is shown below

Moisture	**$Si0_2$**	**Tio_2**	**Fe_2O_3**	**Al_2O_3**	**CaO**	**Na_2O**
10%	9%	13%	41%	19%	3%	5%

In view of fugitive emission, water spraying was the only technology to suppress dust.

In 2012-13, F/A's were informed to explore the possibility of utility red mud in cement industries. In the year 2012-13, F/A's have sold on 49,500 Tons and in the Fy 14 sold 21000.

Udupi Power Corporation Ltd (UPCL) has established 2 x 600 MW coal based thermal power plant at yellow village, Udupi District coal is imported from countries like Indonesia, South Africa and Australia. The minimum and maximum ash contest varies from 1 % to 8 % and sulfur content varies from 0.09% to 0.8% according to sources of coal.

The flyash from ash silos is unloaded through a mechanized system into closed bunker of 20 tons each capacity and is being transported to ash pond. Always film of water is maintained in the ash pond. Always film of water is maintained in the ash pond. Now UPCL has filed with ACC for the same. Initially around 30% of ash was being lifted by ACC by road to other locations. Further utilization fo ash is being explored.

In Raichur, RTPS is a coal saved thermal power station having production capacity of 1470 MW. Total average coal consumption is around 750,000 TPM. Daily around 6528 Ton of flyash is generated. The same was being stored in silo’s. Flyash was further transported to cement industries located in Gulbarga through roads by bulkers. Presently after persuasions by the Board the flyash is transported to cement industries and for manufacture of flyash cement through closed wagons. The total operation is automised and the flyash spillage during handling and transport file is drastically reduced.

The bottom ash is also used for manufacture cement.

In this regard environmental campaign was initiated by Chairperson, KSPCB on 18th July 2013 for utilizing Steel slag as an alternative to sand. Professsor, Department of civil engineering, Indian Institute of Science, Bangalore Dri. P V SIVAPULLAIAH carried out a study on “ASSESSMENT OF SUITABILITY OF GRANULATED BLAST FURNACE SLAG IN EMBANKMENT CONSTRUCTION”. As per the report, the samples having reasonably good angle of internal friction without any cohesion. The CBR values of all the samples are in the range of 16 to 22%. Based on the test results obtained it is recommended that all the slag materials from M/s. JSW Steel Limited, Vijayanagar Works, Kirloskar Ferrous Industries Limited and Hospet Steels Limited can be used in the construction of road embankment as they meet MORTH’s specification.


Flyash-RTPS

Slag from Steel Industry


Indalco, Belagaum

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Sands of Time

POABS Group

For thousands of years, sand and gravel have been used in the construction of roads and buildings. Today, demand for sand and gravel continues to increase. With the growing demand, mining operators, in conjunction with cognizant resource agencies, must work to ensure that sand mining is conducted in a responsible manner. There have been numerous accounts of illegal sand mining and equal amount of efforts taken to curb the same, yet the demand will not cease to exist. POABS envisioned the situation well in time and went on to pioneer in manufacturing sand with Metso technology, which is today's answer to all sand requirement in the country.

Growing concerns

Sand mining is also practised for the extraction of minerals such as rutile, ilmenite and zircon, which contain the industrially useful elements titanium and zirconium. These minerals typically occur combined with ordinary sand, which is dug up, the valuable minerals being separated in water by virtue of their different densities, and the remaining ordinary sand re-deposited. Excessive instream sand-and-gravel mining causes the degradation of rivers. Instream mining lowers the stream bottom, which may lead to bank erosion. Depletion of sand in the streambed and along coastal areas causes the deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets. It may also lead to saline-water intrusion from the nearby sea. The effect of mining is compounded by the effect of sea level rise. Any volume of sand exported from streambeds and coastal areas is a loss to the system.

Excessive instream sand mining is a threat to bridges, river banks and nearby structures. Sand mining also affects the adjoining groundwater system and the uses that local people make of the river.

Instream sand mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Impacts include bed degradation, bed coarsening, lowered water tables near the streambed, and channel instability. These physical impacts cause degradation of riparian and aquatic biota and may lead to the undermining of bridges and other structures. Continued extraction may also cause the entire streambed to degrade to the depth of excavation.

Rising concerns to the alarming situation, of negative environmental impact, has seen strict measures making their way in the southern states of Tamilnadu, Kerala and Karnataka. After banning mining of river sand and other minor minerals without the mandatory environment clearance, the National Green Tribunal (NGT) has recently also banned beach sand mining from the sea coasts of Tamil Nadu and Kerala. Yet, news about illegal sand mining keeps making it's way to the national and regional dailies every now and then. The figures reported to have accounted for loss of minerals through such practices have run into multi-million tones.

Quarrying is thus seen in an unfavorable light because of the environmental impact it has. This is mainly due to de-fragmented operations.

Seeking alternatives

The noticeable effects on environment and the eco system caused by sand mining, together with the growing demand of aggregates to fulfill the construction requirements of the urban world has made it imperative to look for alternate solutions to the concern.

The increasing difficulty in extraction has had a negative effect on the bottom line for many producers. Concrete plants require a consistent, quality sand to optimize their production and minimize their cement usage. In many regions of the world, the extraction of sand and gravel is heavily taxed or banned completely to try to preserve remaining deposits. The industry must find alternatives to meet the growing demand for fine aggregates. Urban expansion and depleted resources have increased the distance between the point of extraction and the point of use. Road congestion has increased the travel time from pit to batching plant for many operators. This, coupled with a decline in the number of pits, has increased prices for the end consumer.

M-sand or manufactured sand is the option. As the natural sand is not replenished at the rate it is being used, the government has begun to promote manufactured sand. Experts vouch that manufactured sand is not only a viable alternative to natural sand, but is superior in many ways. Tests have revealed that the characteristics of mortars and concrete using M-sand as fine aggregate are superior when compared to the natural sand as fine aggregate.

In fact, the 2011 sand policy encourages establishment of manufactured sand units by giving top priority while allotting quarries. The appropriate quality of rock suitable for construction can be used for manufactured sand; there is no clay content; scientifically graded to comply BIS specifications; customizing the different grades depending upon the need of construction; ensures consistent quality throughout the construction cycle.

Foreseeing the future

POABS, is one such organization that read the needs to time and acted well before time to become pioneers in the country to have introduced manufactured sand. Engaging in Crushing and Quarrying activities since 1986, they can also be recognized as the first company in India to produce M-sand for commercial sale. Poabs has always been the first to capitalize on the world's latest techno excellence and equipment support in the manufacturing of crushed aggregates. M-sand is manufactured sand, obtained from specific hard rock (granite) using the state-of-the-art International technology. Its numerous advantages over river sand have made it a favorite and a "Must-to-Use" with quality conscious builders.

In the state of Kerala, the government and the policy makers are pretty stringent about exercising the Health, Safety and Environmental norms. Owing to this it is considered to be a tough challenge to be setting up a plant in Kerala. POABS has always acquired all the environmental clearances for all the projects they lay hands on and concrete using M-sand as fine aggregate are superior when compared to the natural sand as fine aggregate.

In fact, the 2011 sand policy encourages establishment of manufactured sand units by giving top priority while allotting quarries. The appropriate quality of rock suitable for construction can be used for manufactured sand; there is no clay content; scientifically graded to comply BIS specifications; customizing the different grades depending upon the need of construction; ensures consistent quality throughout the construction cycle.

"For us it's a not a problem. Currently all major operations have acquired environmental clearance. Here we have to clear many standards as the environmental committee here has very strict rules & regulations. There are a lot of conditions to be fulfilled." says Mr. Joseph Jacob, Director, POABS Group.

"There is no sand mining in Kerala. The geographical set up of this state is such that the average size is 50km. Altitude variation is (-) 4 feet msl to 8800 feet msl. This span is around 50 km. Formation of sand happens from the top & the mid & lower level is where the sands deposit. Width of the lower region is very limited. And then lower down there are lakes. Lake water gets salty and hence saline problem arises. These factors naturally add to the scarcity of available sand, yet the demand for sand has gone up drastically in the last 50 years, reaching an all time high." adds him explaining.

The state has seen a lot of hurdles and situational instances not allowing it to procure the exact quantity of sand which was required to fulfill the growing developmental projects in the region which include the recent mono rail project in Trivandrum & Metro rails in Cochin & Calicut. These projects are estimated to demand appx 400,000 m□ in 3 years. This is a fairly huge quantity for the Kerala quarries to operate on and suffice for. These projects are still in the process of finalization and policies have to be put in place.

The sands had depleted, but the demand refused to cease. Looking at the geographical condition, the state started importing sand from Tamil Nadu. But slowly the prices went up, factoring the transportation cost.

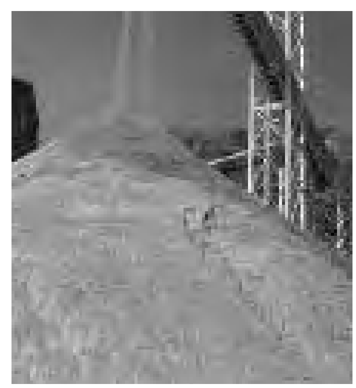
To add to the challenge, in 2008, restrictions were imposed in Tamilnadu which led to not transporting any sand outside the state and further led to an acute shortage of sand eventually. "The Tamilnadu government didn't want to sell their sand to any other state and banned sand mining. Some managed to do it illegally. Then scarcity went up & so did the price. Naturally if scarcity goes up with the demand, the prices are bound to see north. We at POABS initially manufactured sand since 2000 in a very small scale because of production limitation. The prime reason behind it was the higher requirements of fine% & all requirements were to be matched to provide best quality usable sand." recollects Mr. Jacob.

The situation diagnosis

Kerala's resources have more or less depleted. There is no more sand to use and the ban. Some exceptional areas have been permitted, but the whole situation has taken ts toll on the construction segment and also very heavily on the end user.

So what has been one of the prime problems to create demand for manufactured sand?

"The answer is very simple, its lack of awareness" proclaims Mr. Jacob adding, "There is a common perception that river sand is of superior quality.



This myth occurred from the grass-root level as there was a dislike for the manufactured sands with the masons. This was sheerly due to ignorance as they were using crusher dust as Msand.

They were unaware of the difference between crusher sand & M-sand which was proven when we introduced M-sand & asked masons to apply it. They were pretty comfortable and approved of it right away."

The crusher dust is flaky & it sticks while plastering while manufactured sand is graded and cubicle in shape. The angular and flaky nature of the crusher dust makes it difficult and longer for the application to come along. Apparently, the settling time of M-sand is quite less compared to river sand, as the former is graded and has more surface area.

In the market, due to ignorance, one may still get crusher dust as M-sand. It does not pass through the Vertical Shaft Impactor (VSI), and has very high percentage of fine micron. Focusing on the situation in Kerala, Mr. Jacobs says, "River sand is mixed with cement, poured, splashed and left so that the working mason can easily take some time off, come back and finish the job. But because M-sand has more surface area than river sand they have to complete the job faster. So naturally the masons will complain.

Because a larger section of construction is house construction in Kerala, what the masons say has a direct impact on the decision making of the house owner. They also find it comfortable to comply to the recommendation made by the masons than the engineers. We can't blame them also, as when they say they're buying M-sand, they supply normal crusher dust which does not have the required shape. Naturally it will be difficult to work, so they get confused."

Resultant solutions

POABS today has 6 plants in Kerala, 1 in Mangalore and 1 in Tamilnadu. The plant in Tamilnadu is also catering to a portion in Kerala. Initially, the production figures were miniscule but today they are proud to be one of the most prominent players in the market who have been consistently providing quality product to their customers. POABS believes that you cannot make prescribed standard of quality sand without using the best technology in the world and this is where they take immense pride in joining hands with Metso when they decided to pursue this successful venture.

Gradation size and capacity are very important and critical factors today than the traditional approach when less attention was given to sieving either and any machine was being used for the purpose. Working with small machines initially, POABS realized that the sieving area had to be increased and they gradually shifted from a 3 X 1.2m to 4.6m. The challenges were growing and the need for specialized technology rising and Metso came in knocking as the answer to all related worries.

"Earlier M-sand was very difficult to sell even though it was cheaper than river sand and was yet a very price sensitive product. Changing the screens, the classifier and the washing capacity in the VSI, led to us getting more aggregates than fines. The clear option to turn to was Metso. The shape was very important and when we tried to increase the productivity the size wasn't that good. We knew we need a bigger model of Metso's Vertical shaft impactor Barmac B 9150 and the decision was taken in 2009 to start the implementation after seeing the Metso plant in Sweden. We were quite worried about the conditions a bit, but Barmac did an excellent job in converting aggregates to sand. Anything below 20mm were re-circulated in the Barmac and we got a lot of sand.

Resultant was perfect shape with brilliant production figures." says an elated Mr. Jacob. "Not only that but our growth has more than doubled since the use of Metso technology" Mr. Jacob is pretty confident that in the times to come the growth chart is only going to be in their favour with the use of such technology and also the growing awareness about manufactured sand. The recent decision of Public works department, in the mining banned state of Karnataka, to make the use of M-sand mandatory will only help noble manufacturers like POABS to soar production, protect the environment and see enhanced use of specialized technology that can meet quantity and quality needs at all times.

Looking at upwardly growth projections, POABS are looking to add more muscle to their fleet. With a 4 stage plant currently, the aim is to produce more 6mm and 12mm which can be circulated to manufacture sand. While looking to standardize the previous plant, POABS decided wisely to choose the Metso C 125 Jaw crusher to satisfy their primary crushing needs. The need also arose due to some working regulations in Kerala which don't allow quarry owners to practice large blasting as secondary blasting results in a lot of material flying around. This called in for the need of a primary crusher that could be fed larger feed sizes, eliminating secondary crushing entirely.

"Using the C 125 turned out to be a complete winner as it not only solved our problem of feeding large size during primary crushing but also our feeding time from the two C125 as the primary machine, which can be fed easily at a lower elevation helped us control the cost of excavators which usually had to be replaced in 3-4 years, a genuine problem with excavators running on hydraulic brakes. We were so satisfied with the C125 that we decided to change all our primary machines to C125. One smart move begets another and because we were producing sand also we introduced Metso's Barmac VSI into the fleet as well." says Mr. Jacob being analytical.

Barmac once introduced to the circuit smoothened and elevated the operations and gave more fines. This meant more surface area needed for the screens and so POABS introduced 2 screens to the process. This gives a lot of flexibility to operations as when the moisture is high, both the screens are used to increase the surface area. From there on the same pattern was used in all their plants. C125 + B9100 + 2nos. (6x2) CVB screens is the standard configuration for all POABS plants.

Fitting the fittest

With a rise in demand of M-sand rose the idea to start and expand sand manufacturing and thus a need for the best in class facility and technology to support and sustain the idea in the long term. Looking for the right technology and expertise POABS approached Metso but was a little unsure about the equipment manufacturer's initial proposal. A little more research on the Metso website to enhance the knowledge on sand manufacturing and best technology & practices helped POABS a lot to build up on their own information and also take the right decision.

"Metso website helped us a lot, worked almost as a guide to beginners or experts alike. We were seeking quality information on sand manufacturing and Metso website almost like opened a treasure box for us. Numerous case studies with flowcharts, diagrams, photographs of projects & specific detailing was enough even for a novice to gear themselves up for the expert mode. With the information now in hand we compared all the data for the types of sands." he said, adding "One section had Barmac for sand production. Earlier we were not convinced that Barmac can produce sand as we doubted the rock on rock technology beyond a certain level. We thought recirculation will only increase & the size may not be proper going up to be unsure about even the size of the machine. Cone, Barmac or Rollers was a question circling our thoughts. "

All questions were answered well in time with all the information available that helped quick analysis and concluded that Metso Barmac will be the best machine to fit requirements and had the potential to meet needs. The size and capacity were also up to the mark and because there was a fair amount of recirculation required POABS decided to go with the higher capacity machine. Also, interestingly while browsing through the numerous successful cases on the Metso website, the M-sand producers stopped upon a case of Metso Barmac producing sand in China. The referred project used 4-5 Barmac crushers using river sand for the production of sand to build a dam. This helped seal the decision on trying out Barmac.

The online research also updated POABS that if the feed is less than -25mm they get more sand. They immediately decided to send some samples to Metso lab. The question was that the throughput of Barmac was 350 tons, if they could provide for ample feed. Wisely, they decided to go for a larger hopper & a storage bin which could add to the surge and built a surge hopper between the Barmac & the recirculation path. The material then sent for testing confirmed that they can produce around 100 – 150 tons depending on the feed and the first trial was underway.

"We ordered the machine but there was some delay in the project in Tirulla. So we decided to immediately start the project in Trivandrum. We had the washing arrangement in place and so we kick started the production right away. In the initial trials only, we were convinced of the Barmac & its sand production capacity. To my surprise, we were feeding 12mm and getting 90% sand in the initial run. These figures were high and satisfactory. We had a higher capacity Barmac but didn't know whether we could give proper feed to it so we were running the feed batch wise until the Air Classifier was commissioned. We have come a long way after that and now we are commissioning the 7th plant, where without a doubt we placed the order for a Metso Barmac crusher as well."

Upon the expert advice and the best equation for the modified plant, Mr. Jacob said, "Our earlier project, which we completed in a short span, had a limited area. While commissioning, familiarity was more with flat terrains. To build a 100m x 100m in that terrain is quite a task & in Kerala, the plant has to be covered from all sides as per environmental norms. We showed the existing plant to Metso professionals and asked to size it down as per our requirements. Although the design had to be changed later, as the regulations in Kerala keep on changing a number of times. But despite of all the difficulties, Metso worked as one with us, were very cooperative & did an excellent job.

We changed the design about 14 times for the same plant. The conveyor has been designed to be 27m (80 feet) high, so as to give more dropping / storage space to the sand falling from the conveyor. Design aspects were a good learning for me also. Fitting such kind of a capacity in the available area is a feat in itself, truly the work for an expert. The plant was completed in almost

4.5 months with 2 teams working together with Metso experts. This could happen only because of Metso's unmatched will & cooperation."

All in all, POABS is a happy customer as affirmed by Mr. Jacob, who also likes to call the equipment as 'Zero problem machines' and have also ordered the Metso HP300 cone crusher lately, while mentioning the brilliant results they have obtained from the GP200. Talking about the equipment it seldom happens that Metso service won't get acknowledged as that's what's Metso's chief success mantra is. Sounding extremely satisfied with the field response time and also the service in general, he also mentioned his desire to see more training sessions being conducted by Metso to train their staff on equipment and best sustainable practices.

"We majorly focus on preventive maintenance. We don't move our machines from project to project, our machines are stationary, hence you won't get the time to stop the machine and service it. So its better we take steps towards preventive maintenance. I must say working together as a team with Metso has only made things easier and smoother." he added.

Awareness is the need of the hour POABS emphasises that the government should also take measures to come up with norms and/ or standardize production of M-sand. Listing of manufacturers, grading system, etc, will ensure the quality of Msand and reduce the supply of inferior quality product in the market. It is also essential to create awareness on the use of M-sand for construction purpose and scarcity of river sand.

Mr. Jacob also mentioned the safety issues, problems faced by the crusher owners due to lack of trained people for blasting which cause accidents at the quarry, environmental issues, local people resistance, etc. Due to non availability of trained people for the quarry blasting, all major crusher owners have planned to start a training centre for the quarry blasting which will be inaugurated very soon. They often take care of the local roads leading to the quarry/crushing site to appease the locals.

Environmental clearances are a big hurdle for a crusher owner but a sustainable practice at large. "There is a high demand for manufactured sand in the market. The government should take initiatives to convince the concerned agency, like PWD, to use re-processed Msand rather than using the unprocessed quarry waste powder, which is much cheaper in quality as well as value.

Kerala has more rain than other states, hence the material used should be of extremely good quality which can be produced by using Metso equipment as they provide better better productivity han other machines, any given day." concluded a satisfied Mr. Jacob.

Article Source : www.metso.com
Courtesy : Joseph Jacob
Director, POABS Group, Kerala

Bureau of Indian Standards Specifications for Fine Aggregates Used for Various Applications other than Cement Concrete

Compiled by Dr. R. Nagendra

INTRODUCTION: Fine aggregates are used for making cement concrete, bituminous concrete, masonry mortars, plaster, filter media etc. Bureau of Indian standards in its various publications has brought out specifications of fine aggregates for the above mentioned applications. Specifications are compiled for some of the applications are given below:

1. SAND FOR PLASTER

Specifications of sand for plaster is stipulated in IS 1542: 1992 (Reaffirmed 1999) and includes naturally occurring sands, crushed stone sands and crushed gravel sands used in mortars for internal walls and ceiling plastering.

Quality of sand: The sand shall be hard, durable, clean and free from adherent coatings and organic matter and shall not contain clay, silt and dust more than specified below:

i) Clay, silt and dust determined as per IS 2386 (Part 2): 1963 shall not be more than 5% by weight.

ii) Organic impurities determined as per IS 2386 (Part 2): 1963- Colour of liquid below that indicated by comparison with the standard solution specified in 6.2.2 of IS 2336 (Part 2): 1963.

Compressive Strength: The average compressive strength, determined by the standard procedure detailed in Appendix A of IS 2250: 1981, of mortar cubes composed of one part of cement and six parts of conforming to gradation in Table 1 shall not be less than 3 N/ mm2 at 28 days. The amount of water for gauging shall be that required give a flow between 110 to 115 with 25 drops in 15 seconds, as determined in Clause 9.5.3 of IS 1727:1967.

Table 1 Grading of Sand for Internal Wall or External Wall or Ceiling Plaster

IS Sieve Designation	Percentage Passing
10 mm	100
4.75 mm	95-100
2.36 mm	95-100
1.18 mm	90-100
600 micron	80-100
300 micron	20-65
150 micron	0-15
NOTE: For crushed stone sands and crushed gravel sands, the permissible limit on 150 micron IS Sieve is increase to 20 percent. This does not affect the 5% allowance permitted as per Clause 5.1 of IS 1542:1992.	

Fineness Modulus: The fineness modulus of sand shall not be less than 1.4 in case of crushed stone sands and crushed gravel sands and not less than 1.5 in case of naturally occurring sands.

2 SAND FOR MASONRY MORTARS:

Quality of sand: The sand shall be hard, durable, clean and free from adherent coatings and organic matter and shall not contain clay, silt and dust more than specified below:

i) Clay, silt and dust determined as per IS 2386 (Part 2): 1963 in natural sand or crushed gravel/ stone sand shall not be more than 5% by weight.

ii) Organic impurities determined as per IS 2386 (Part 2): 1963- Colour of liquid below that indicated by comparison with the standard solution specified in 6.2.2 of IS 2336 (Part 2): 1963

Table 2 Grading of Sand for use in mortars

IS Sieve Designation	Percentage Passing
4.75 mm	100
2.36 mm	90-100
1.18 mm	70-100
600 micron	40-100
300 micron	5-70
150 micron	0-15

3. SAND FOR USE AS FILTRATION MEDIA IN FILTRATION OF WATER

IS 8419 (Part 1)-1977 lays down the requirements for filter sand and for gravel used in filtration of water.

Quality Requirements:

i) Filter sand shall consist of hard, durable grains of silica and shall have a specific gravity of not less than 2.5. All grains of sand shall be preferably be water worn.

ii) The minimum silica content in sand as determined by method given in Clause 7 of IS: 2000-1962 shall be 90%

iii) Any sample of filter sand shall not contain more than 5% of acid soluble matter as determined by a solubility test described in Appendix B.

iv) The loss of ignition, which is a measure of the organic matter present in sand, and determined by the procedure given in Appendix C shall not be more than 0.7%.

Dr. R. Nagendra
Technical Director
Civil-Aid Technoclinic Pvt. Ltd.,
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PROMAN provides crushing solutions and we believe that our equipment is a part of the total solution which involves the process, the application and the system. We spend a lot of time to understand customer requirements and ensure that we educate the customers so that he takes the right decision **PROMAN**'s usp is to provide innovative crushing solutions with our collaborations in technology from world class crushing and screening equipment. **PROMAN** is known for providing crushing solutions, which are customized to the segment or industry.

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UltraTech's parent company, the Aditya Birla Group, is in the league of Fortune 500 companies. It employs a diverse workforce comprising of 1, 33,000 employees, belonging to 42 different nationalities across 36 countries. A recent survey conducted by Aon-Hewitt ranked the Aditya Birla Group as one among the **'Best Employers'** in India. Another survey conducted by Aon-Hewitt, Fortune magazine and RBL ranked the group as No. 4 in the world and No.1 in Asia Pacific among the 'Top Companies for Leaders' (2011)

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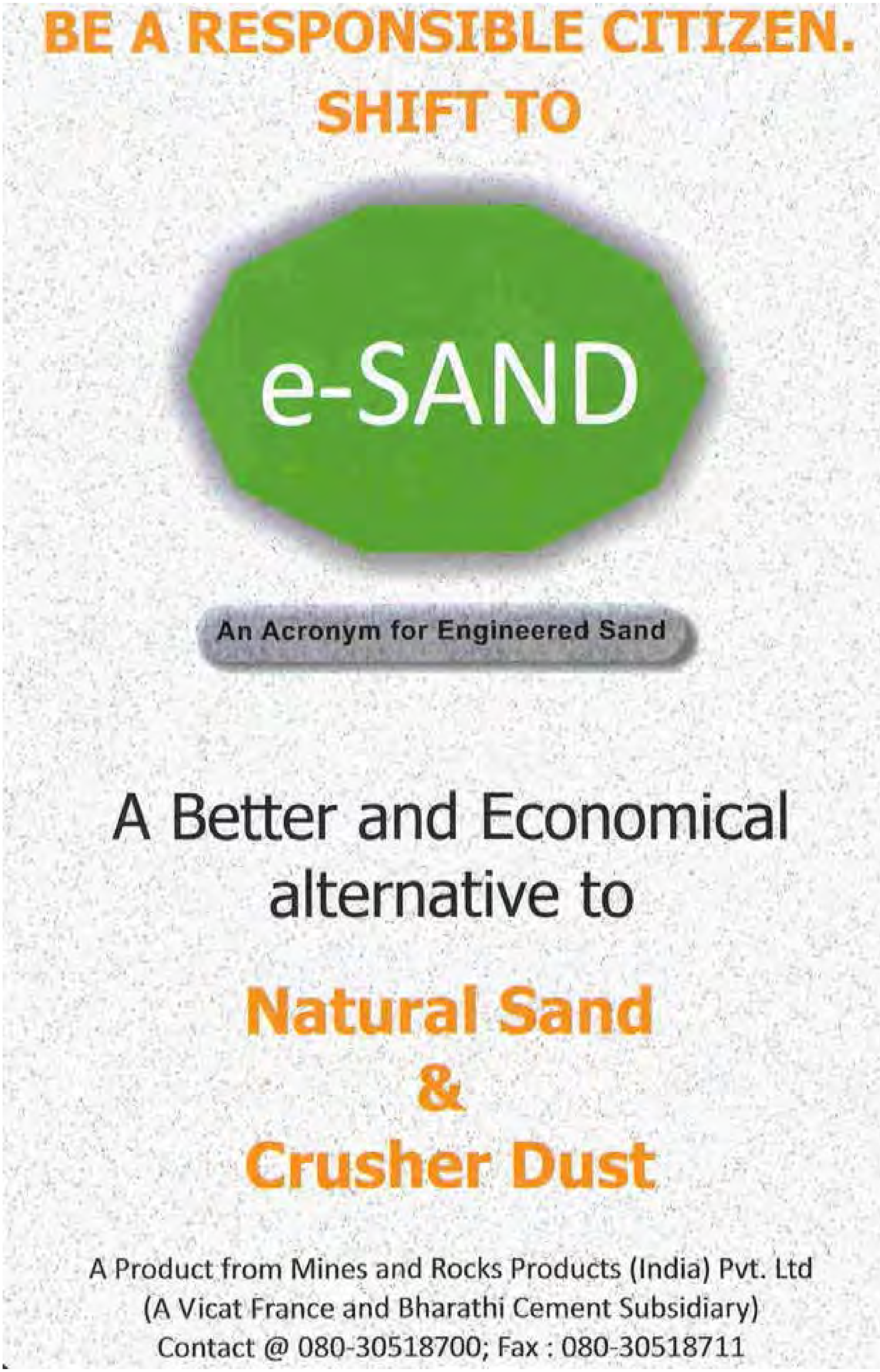
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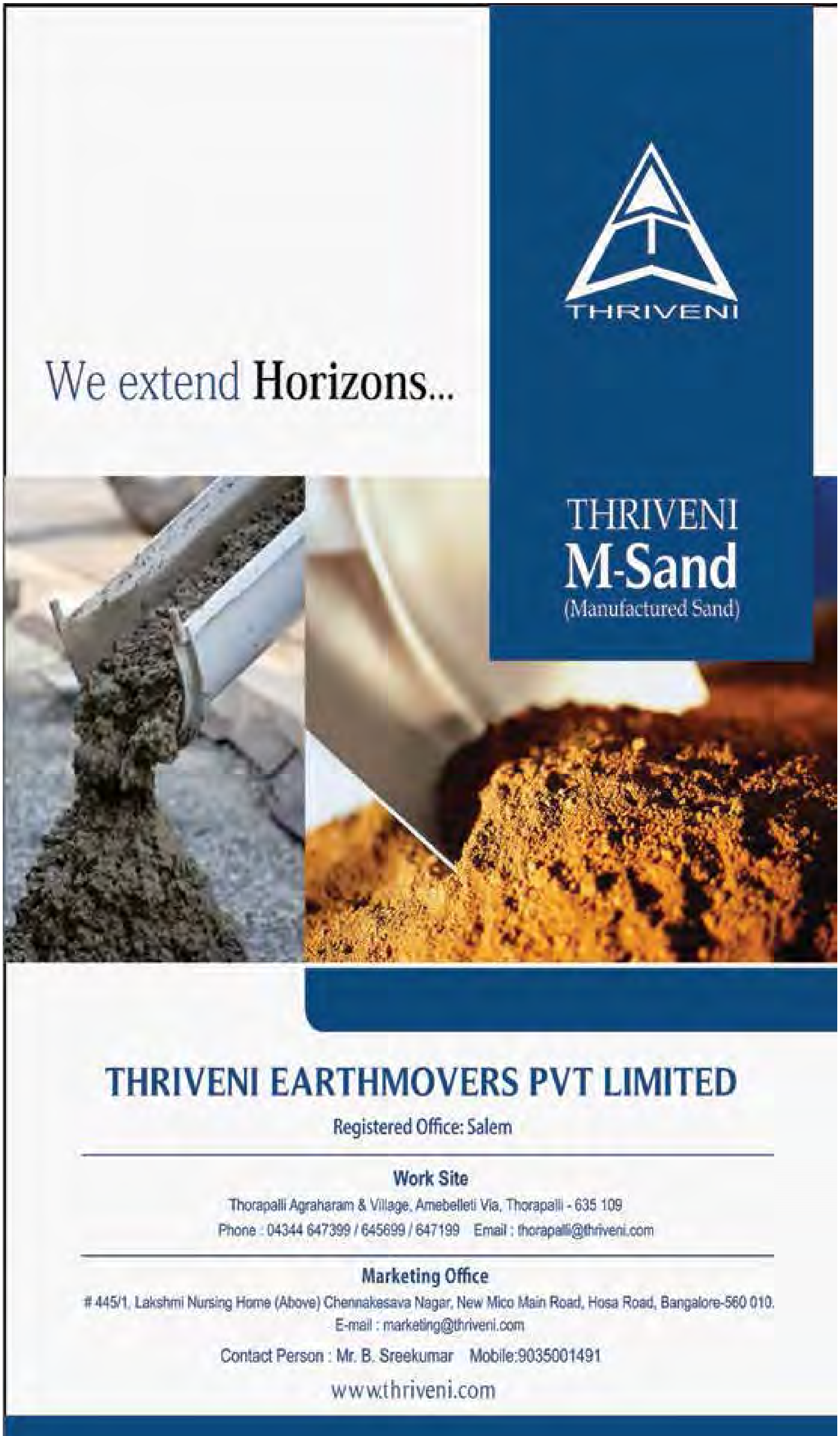
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