Indian Concrete Institute, Bengaluru Centre

Seminar on

BETTER AGGREGATES FOR CONCRETE & ALTERNATIVES TO RIVER SAND

7th December 2017

at **The Capitol,** Rajbhavan Road, Bengaluru, INDIA.

PROCEEDINGS

INDIAN CONCRETE INSTITUTE – BENGALURU CENTRE

#2, UVCE Alumni Association Building, K. R. Circle, Bengaluru-560 001.

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ICI – Bengaluru Centre

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Indian Concrete Institute, Bangalore Centre

Presents

One Day Seminar on

BETTER AGGREGATES FOR CONCRETE & ALTERNATIVES TO RIVER SAND

7th December 2017, Thursday

Venue: The Capitol Hotel, RajBhavan Road, Bengaluru.

Indian Concrete Institute - Bangalore Centre, Karnataka

No. 2, UVCE Alumni Association Building, Dr. B R Ambedkar Veedhi, K R Circle, Bengaluru - 560 001

Tel: 080-2222 4803 / 0-98861 27398 Email: icikbc@gmail.com Website: www.icikbc.org

INTRODUCTION:

High quality Buildings and Infrastructure projects are possible only by ensuring consistent good quality materials and processes. Concrete has played and continues to play a pivotal role in the Construction Industry. As a basic but vital Construction Material, the versatility of Concrete is unparalled. In fact, as on date, there is hardly any alternative available. Fine and Coarse Aggregates form the vital building blocks of Concrete. They determine the functionality and durability aspects to such a large extent that any compromise in quality or quantity of these, make the Concrete redundant from intended use.

Sourcing of quality Aggregates has become a challenge in recent times. Increased awareness of the catastrophic effect of mining on River Sand has highlighted rapid Environmental degradation which is unacceptable. To address these challenges, innovative approaches need to be adopted to identify equivalent or better alternatives so as to ensure sustained supply and enhanced performance of the Aggregates in Concrete.

Indian Concrete Institute–Bangalore Centre, Karnataka has always been at the fore-front of identifying such challenges in early stages and facilitate quick but resilient solutions. ICI-BC has played and continues to play a pivotal role in the dissemination of application-oriented knowledge to its members and the Construction fraternity. In this endeavour, ICI-BC is organising this One Day Seminar aimed at Civil Engineers, Architects and all those connected with the Construction & Infrastructure Sector. In addition, Aggregate manufacturing companies, Equipment manufacturers and Governmental decision makers are also expected to participate.

The Seminar is intended to serve as a platform for appraising and articulating on latest development in aggregates that form an integral form of good quality Concrete.

Lectures / interactive sessions by eminent Speakers, in the Seminar, include the following:

- Manufactured Sand / Slag Sand
- Crushed Stone Sand, Plaster Sand, latest revision in Codal Provisions
- Pond-ash as Alternate to River Sand
- Aggregate manufacturing machinery
- C&D Waste (Construction & Demolition Waste) as Aggregates
- Panel Discussion on Aggregates

Who should participate:

Practising Civil Engineers, Governmental Agencies, Entrepreneurs, Consultants, Contractors, Developers, Builders, Researchers, Academicians, Equipment manufacturers, Ready-mix Concrete manufacturers, Building material suppliers and all those related to the Construction and Infrastructure Industry.

DELEGATE FEE:

Members of ICI, ACCE, INSTRUCT :
₹ 2,000 + GST@18% = ₹ 2,360/-

Non-members :
₹ 2,500 + GST@ 18% = ₹ 2,950
(Delegate fee includes Seminar Kit, Lunch, Tea)

Fee can be paid through Cheque / DD / Cash / RTGS. Delegates are requested to send a mail after the payment of registration fee quoting transaction reference number, their Name, Designation, Address, Email ID and Phone No. to icikbc@gmail.com or call 080-22224803 (10 am to 6 pm on any working day).

For Payment through online banking, please note the following details:

Electronic Transfer	: RTGS / NEFT Details;
Account Name	: Indian Concrete Institute – Karnataka Bangalore Centre
Account No.	: 04121010000530
Account Type	: Current Account
Name of Bank	: Syndicate Bank
IFSC Code	: SYNB0000412
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1. **Platinum Sponsor:** **₹ 75,000/-** (includes free admission to 3 delegates + insert of Three technical literatures in Delegate Kit). Presentation slot of 7minutes will be allowed.
2. **Gold Sponsor:** **₹ 50,000/-** (includes free admission to 2 delegates + insert of Two technical literature in Delegate Kit)). Presentation slot of 5minutes will be allowed.
3. **Supporting Organisation :** **₹ 25,000/-** (includes free admission to 1 delegate + insert of One technical literature in Delegate Kit)
4. Insertion of Book + Pen in Delegate Kit by Corporates: **₹ 10,000/-**
5. Insertion of Marketing collaterals in Delegate Kit: **₹ 10,000/-**
6. Additional Marketing opportunities exist. For details and price, please contact ICI Bangalore Centre at address mentioned in this Brochure.

*(exclusive of GST). Technical literature/brochure/ inserts in Delegate kit shall be provided by Sponsors/ Corporates.

For Registration, please contact:

Indian Concrete Institute - Bangalore Centre, Karnataka

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Tel: 080-2222 4803 / 0-98861 27398 Email: icikbc@gmail.com Website: www.icikbc.org

Er. Ravishankar M
Chairman, ICI-BC

Dr. Radhakrishna
Secretary, ICI-BC

Er. H.R. Girish
Working Committee for Seminars, Conferences, Workshops

CONTENTS

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ABOUT INDIAN CONCRETE INSTITUTE BENGALURU CENTRE

Indian Concrete Institute (ICI) is one of the leading professional bodies in India, catering to the professional needs of individuals and organisations involved in the field of Concrete. ICI is a non-profit Organisation, dedicated to the cause of dissemination of Knowledge on Concrete, to Promote Concrete Technology & Construction and to address the Research Needs of Concrete.

ICI was founded in 1982 with around 500 members from 5 regional Centres. Since then, ICI has grown and expanded substantially. Today ICI has earned the reputation of being a respected professional body, having more than 12, 000 members, from 38 regional Centres across major cities. Of these, more than 270 are Organisational Members. All segments of Cement and Concrete industries are widely represented in the membership of ICI.

To meet the objectives of ICI, the Regional Centres conduct various programs viz., Seminars, Workshops, Conferences, Exhibitions, Deminars etc., all round the year. These are at both National and International levels. These events have proven to be an unique platform wherein various stakeholders in the concrete industry, Practicing Engineers, Manufacturers, Academicians, Consultants and Researchers participate actively at local as well as global levels, to discuss issues, share views & experiences on aspects related to Concrete and releated matters. ICI derives deep synergy amongst the various categories and diversities of its members and Industry associated with concrete.

ICI – Bangalore Centre, Karnataka was started in 1984. Right from start, ICI-Bengaluru Centre has the coveted distinction of being a high-performing Centre through adoption of professional and progressive managing method. It is the amongst the largest and most active centres which conduct several programs every year. Its membership continues to grow on a continuous and commendable basis. In addition to practicising professionals, ICI-BC includes chapters at various District Head quarters and 33 Student's Chapters.

For more information about ICI-Indian Concrete Institute, Bengaluru Centre, please visit: www.icikbc.org.

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Dr. M. U. Aswath
Chairman-ICI Technical Committee TC07

Chairman's Message

I bring greetings from Er. Vivek Naik, President ICI, Er. Vinay Gupta, President Elect ICI, Mr. R. Radhakrishnan, Secretary General, ICI and all the GC members of ICI.

Indian Concrete Institute (ICI) is the national organisation of engineering professionals, employed in concrete construction and associated research in India. It was founded in 1982 in Chennai following a resolution in the International Seminar and Exhibition on 'Modernization of Concrete Practices' organised jointly by the Structural Engineering Research Centre (SERC) and Anna University.

The ICI imparts training to working professionals in changing technologies in concrete constructions, promote research work in concrete technologies, publish journals on research finding, newer technologies and solution for practical problems, collaborate with agencies employed in concrete construction, research and associated manufacturers for better adoption of the technology by working professionals

The services of ICI include; conducting programs, trainings, certificate programs, concrete days, Endowment lectures, supporting student chapters, bringing out publications, ICI monographs, special publications, ICI Journal, ICI Updates and recognizing the professionals by annual awards.

In order to serve the professionals to provide latest knowhow , ICI has constituted various technical committees on Fibre reinforced concrete, precast construction of buildings, concrete admixtures, unified code for concrete construction, recycling of aggregates for C&D wastes, decorative concrete, alternatives to river sand, concrete durability, concrete flooring and white topping etc. the objective of these committees is to bring out technical documents like reports, guidelines, specifications, manuals, recommendations, hand books etc, by pooling up expertise available within and outside ICI.

ICI works in close coordination with various Central and State Government bodies, BIS codal committees. ICI is an active participant in Asian Concrete Federation (ACF) for which Dr. Manamohan R Kalgal, Immediate past president of ICI is now the vice president. ICI has signed MOU with Singapore Concrete Institute, Concrete Institute of Australia, Korea Concrete Institute, American Concrete Institute and RILEM for exchange of technological information, technical documents and to organize programmes jointly.

The recently launched ICI Technology centre conducts certificate courses on concrete technology. ICI also provide E-learning portal and Job portal assistance through its website: http://www.indianconcreteinstitute.org/servicess.html

I am very happy to note that ICI-Bangalore Centre is one of the best centers of ICI and very active in achieving the objectives of ICI. I wish the One-day Seminar on "BETTER AGGREGATES FOR CONRETE AND ALTERNATIVE TO RIVER SAND" on 7th December 2017 at The Capitol Hotel, Bengaluru, a grand success. I am sure the deliberations will add value in promoting best practices for the betterment of the construction industry.

I congratulate the Bangalore centre chairman Er. M. Ravishankar, Secretary Dr. Radhakrishana and the program coordinator Er. Girish H R and team for their excellent work.

Dr. Aswath M U
Vice president -South

Er. Ravishankar
Chairman – ICI-BC

Chairman's Message

Availability of good quality River Sand is becoming extremely difficult in most parts of our country. In addition, illegal and indiscriminate mining of River Sand leads to major environmental issues. Hence the Construction industry, in particular the Ready-mixed Concrete industry, started using alternates to River sand like Crushed stone sand (CSS), Manufactured sand like Granulated Blast Furnace Slag (GBFS), Copper slag sand, Crushed stone plaster sand, etc.

In order to create more awareness and to clear any concerns, this One day seminar on "Better Aggregates for Concrete and Alternatives to River Sand" is being organised by the Indian Concrete Institute (ICI) – Bengaluru Centre (BC) on 7th Dec 2017. Experts from the Industry and Research will be discussing, in detail, on alternate materials that are practically available in the market.

I am sure this one day Seminar will be a relevant program addressing the need-of-the-hour and all delegates will be immensely benefitted from this program.

On behalf of Managing Committee, Indian Concrete Institute, I express our sincere thanks to all Sponsors, Supporting organisations, all companies & Institutions for registering the delegates and all associates who have helped us in organising this program.

We look forward to organise such programs on Specific topics of interest to concrete Professional in the construction industry in the near future. We look forward for your continued support in all ICI – BC activities.

Thanking you one and all.

Ravishankar M
Chairman
Indian Concrete institute
Bengaluru Centre

Dr. Radhakrishna
Secretary, ICI-BC

Secretary's Message

Indian Concrete Institute - Bengaluru Centre is active in disseminating knowledge to field Engineers, Consultants, Manufacturers, Academicians, Students etc. There is a gap between the facts and practice in making better concrete. This seminar would try to bridge this important lacuna. The eminent speakers will be able to present the best picture of making concrete using sustainable aggregates. Panel discussion will throw more light on real challenges in the field. All the participants are requested to make use of this opportunity and practice in the field for better construction practices. I wish all the participants good luck.

Er. H. R. Girish
Working Committee – Seminars, Conferences, Workshops

Intent Behind This Seminar

Construction & Infrastructure Sector continue to play a pivotal role in the growth & prosperity of our Nation. With India emerging as an important contributor to growth across the world, it is being looked upon as an important ally to support various crucial developmental works not only in developing countries but in advanced countries as well with the most tangible cooperation indicator being in the Construction and Infrastructure sector. It is therefore pertinent that our professionals in the Industry are update with the latest and best practices with respect to the materials of construction, amongst other relevant body of knowledge.

Aggregates form a vital ingredient and are fundamental materials in almost all Construction activities. The decades-old practice of mining Sand from River banks/ beds has lead to catastrophic consequences leading to prohibition on River Sand mining. Against such a scenario, it becomes imperative to be aware of Alternatives to River Sand and better Aggregates. Aspects such as material-property, manufacture, sourcing and use of Aggregates are vital for selection and use of right Aggregate. Concrete is a fundamental building block and is the largest consumed construction material in composite form, with Aggregates forming its vital components.

In order to update / refresh the knowledge of practising Engineers and various stakeholders to these important materials viz., Fine and Coarse Aggregates, this Seminar is being conducted by the Indian Concrete Institute – Bengaluru Center, as part of its ongoing endeavour to disseminate knowledge in Concrete, Aggregates and relevant materials for the benefit of all those working in the Construction, Infrastructure and Supporting Industries. In this Seminar, emphasis is on the application-oriented approach and dynamic exchange of on-site experiences with respect to Aggregates so as to provide solution to strategic decision making on selection and use of the right type of Aggregate.

Slag Sand – An Eco-Friendly Fine Aggregate

S M R Prasad

Alternative Aggregates

- **To reduce the burden on the environment, alternative aggregates have been extensively investigated.**

- **Looking to the quantum of requirement, quality and properties future lies with one material - Slags**

- **Slag aggregates has been proven as a suitable material for replacing natural coarse and fine aggregates .**

- **In all developed countries, the use of Slags as aggregates to replace natural sand/rocks is well established and is in regular practice.**

What is slag ?

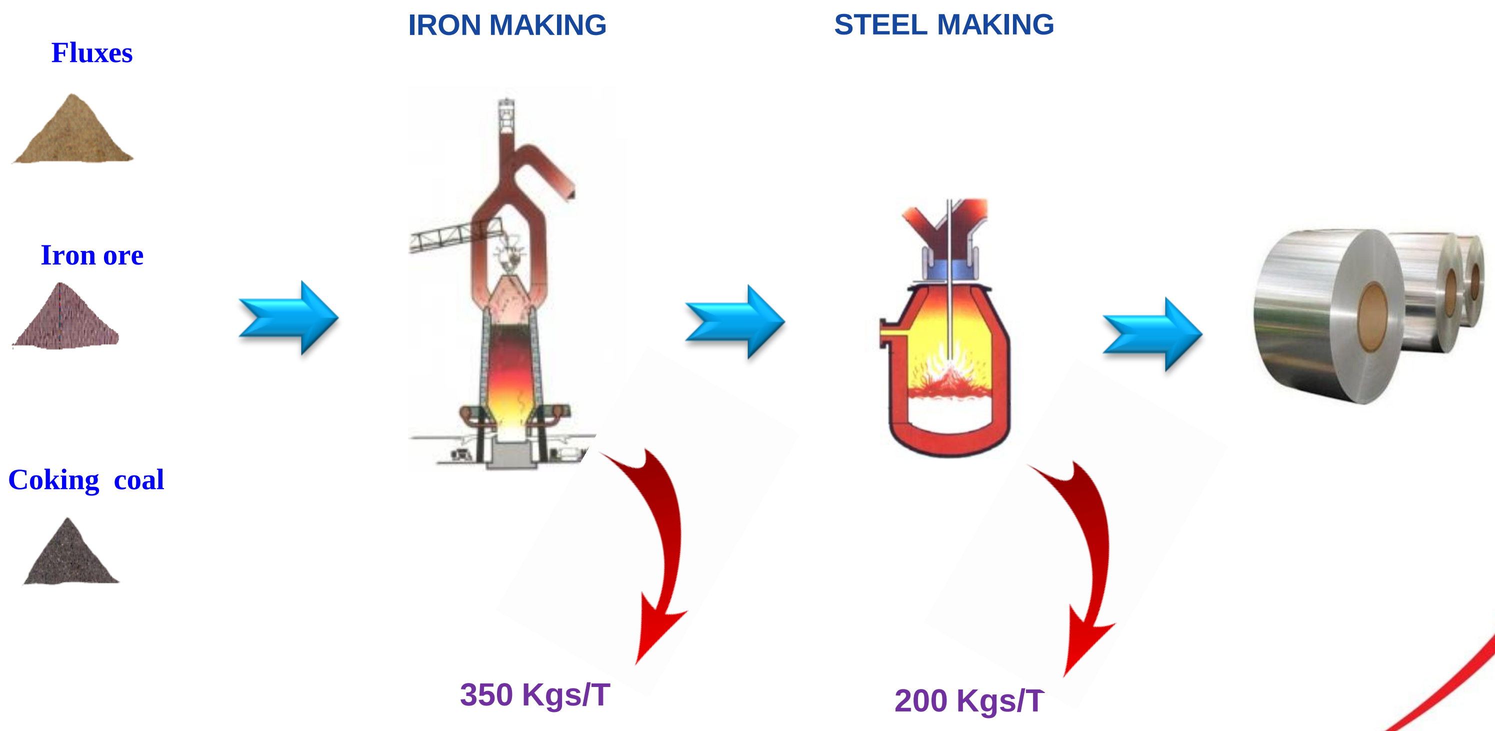
- **"Slag" is a non-metallic product, consisting of glass containing silicates and Alumino Silicates of lime produced in steel industries.**

- **Slag is a byproduct of metal smelting processes, Manufactured under quality-controlled conditions.**

- **Granulated slag is obtained by rapidly chilling (Quenching) the molten slag from the furnace by means of water or steam and air.**

- **Does not contain organic matter, clay, silt and shells.**

Slag Generation

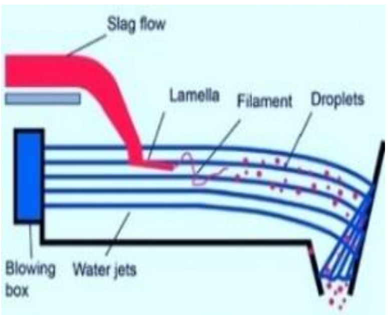


Slag Dumping




STEEL MAKING

IRON MAKING



Granulated BF Slag

Fine

Air Cooled LD Slag

Coarse


Slags as Aggregates - Issues

- **Properties differ from natural aggregates specifications**
- **No standards or specifications for alternative aggregates**

Granulated BF Slag as Fine Aggregate (River sand)

Fine Aggregate

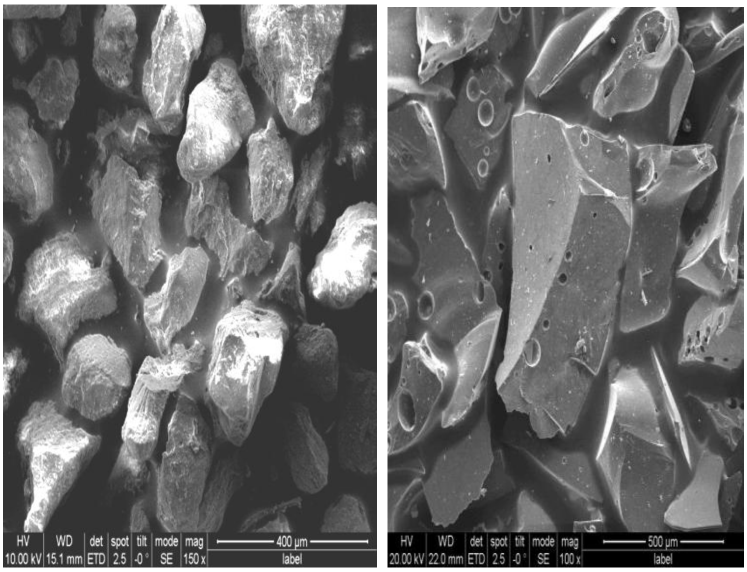
GBFS can replace Sand

If meets specs of IS-383

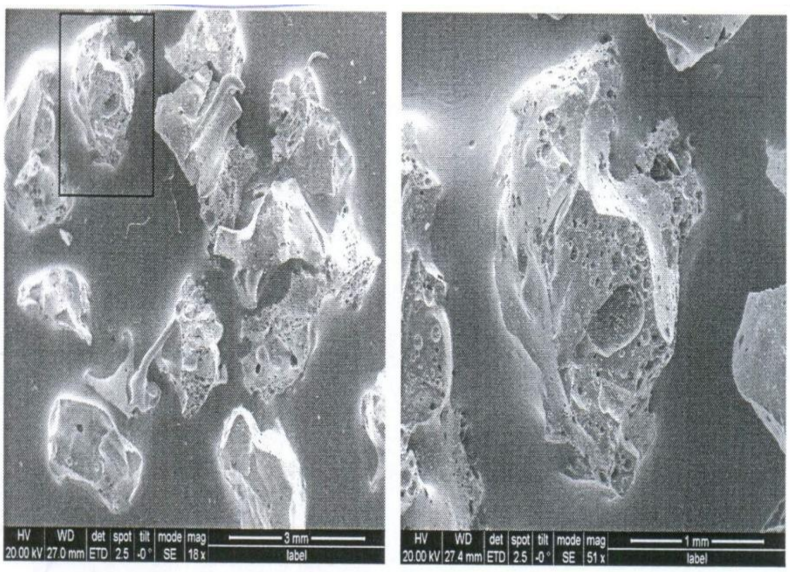
- Size
- Deleterious Material
- Soundness
- Bulk density
- Sp Gravity
- Water absorption

PROPERTIES	RIVER SAND	GBFS
Size	IS 383 - Zone II / Zone I	IS 383 - Zone II / Zone I
Deleterious Material	0.2 %	Nil
Soundness	Good	Good
Density, Kg/m3	1400 - 1700	1000 - 1100
Sp Gravity	2.6 - 2.8	2.3
Water Absorption	1 – 3 %	4 -6 %

Comparison of River sand and Granulated BF Slag



River Sand

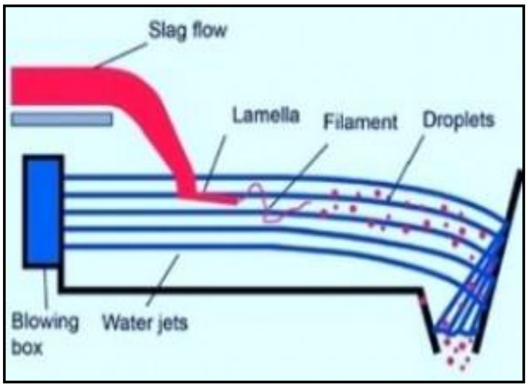


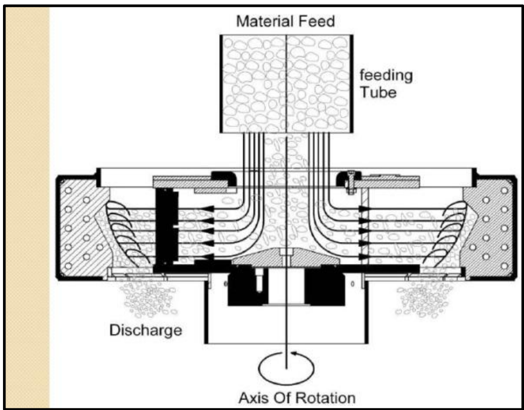
Granulated BF Slag

Lower density in slags is due to its vesicular structure with presence of micro pores

Processing of BF slag

- **Step 1: Altering granulation parameters**
- **Step 2: Shaping and Screening**

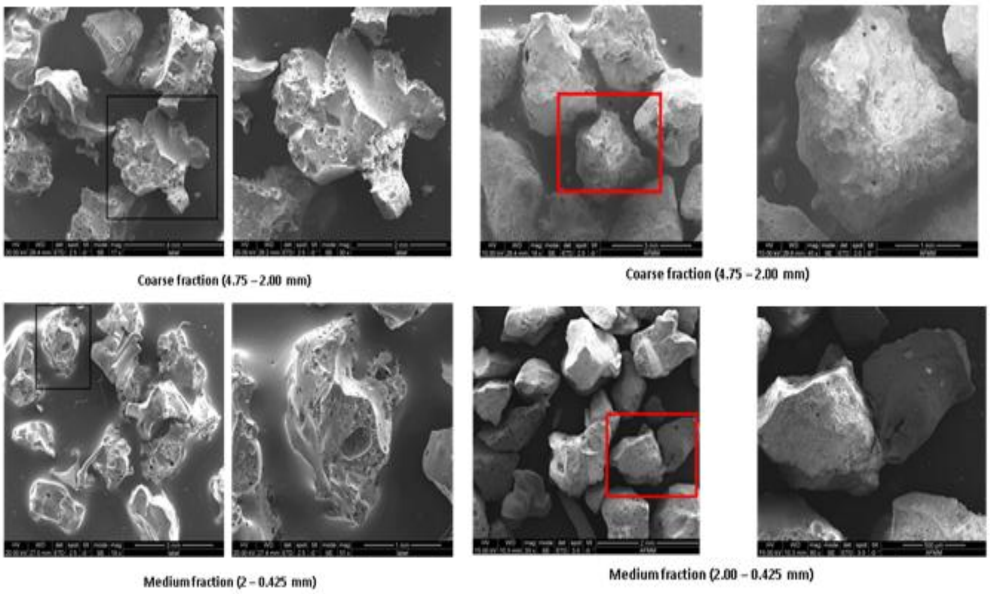




Processed Granulated BF slag

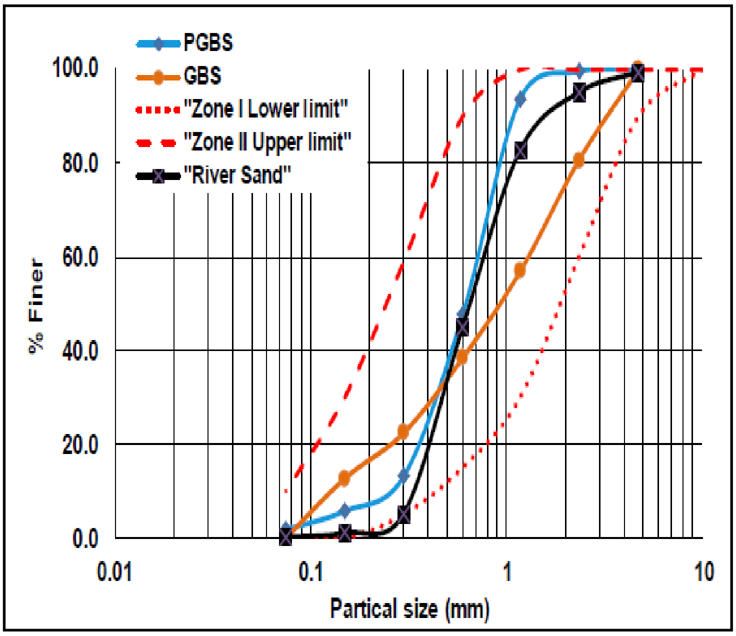
- Particles shapes have improved.
- No sharp edges and the needle shaped particles.
- The processed granulated blast furnace slag (PGBS) was similar to true river sand

Granulated BF Slag

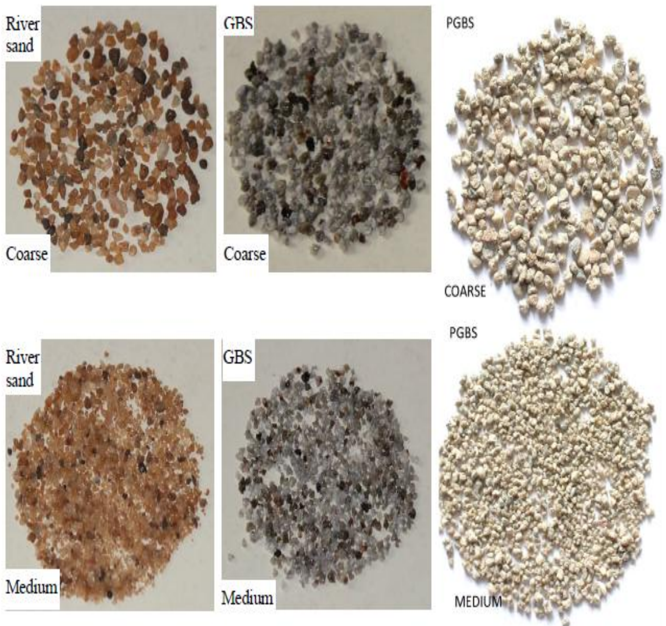


Processed Granulated BF Slag

Processed Granulated BF slag



Gradation



Size and Shape

Properties

PROPERTIES	RIVER SAND	GBS	PGBS
Size	IS 383 - Zone II (Fine)	IS 383 - Zone I (Coarse)	IS 383 - Zone II
Density, Kg/m^3	1400 - 1700	1000-1100	1500
Sp Gravity	2.6 - 2.8	2.3	2.65
Water Absorption	1 – 3 %	4 -6 %	<3%

Advantages Over River Sand

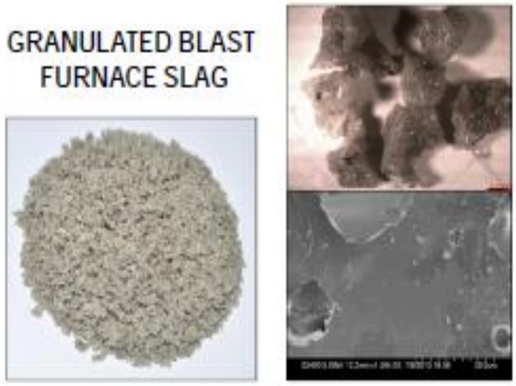
	RIVER SAND	SLAG SAND
Marine Products	2 - 4%	Nil
Oversized Materials	6 - 10%	Nil
Clay & Silt	5 - 20%	Nil

Chemical Tests - Inert

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 Magnesium Sulphate	1.70 2.08	Max. 10% 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).		

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

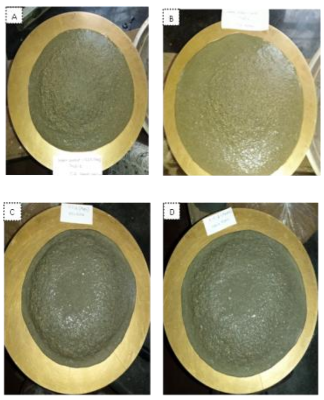
Microscopic Examination



- Shape of the granulated slag sand is similar to river sand.
- Microscopically also, river sand and manufactured slag sand are similar.

Can be used 100 % individually and also in combination with River sand, Crusher Dust and M-sand

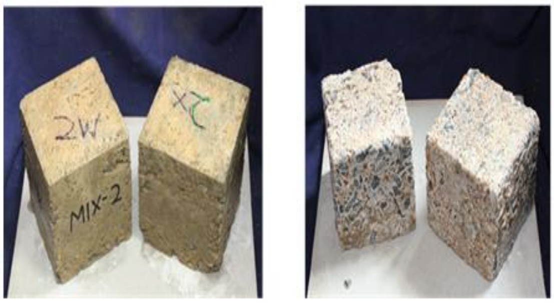
Mortar/Concrete Tests



Flowability

Cube Testing

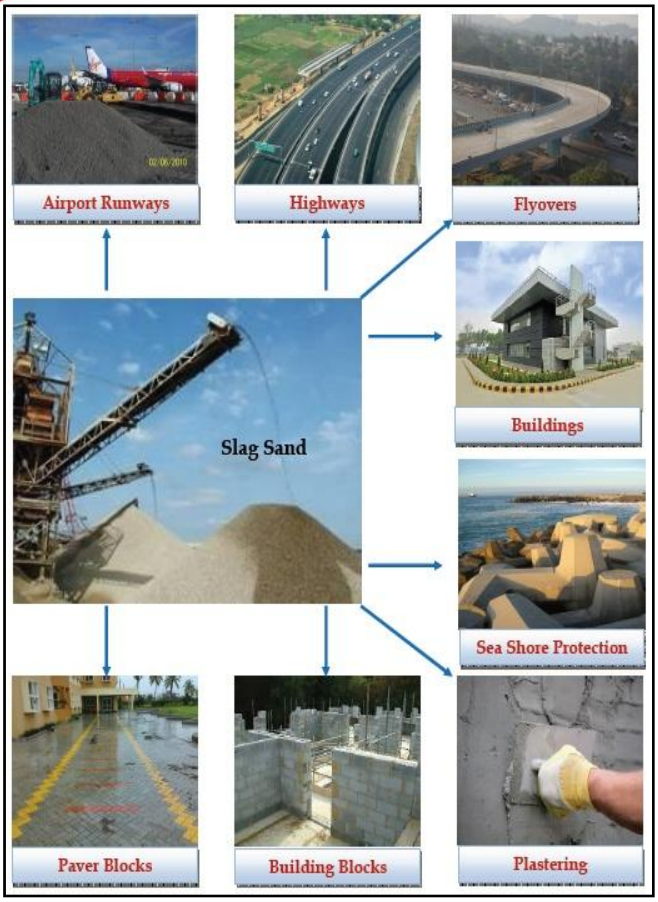
Durability



Fine Aggregate	7th day Strength (N/mm^2)	28th day Strength (N/mm^2)
100% Natural Sand	38-42	48-52
100% GBS	36.5	45.5
100% PGBS	42.9	53.3
50% PGBS + 50% NS	39	52
50% PGBS + 50% M - Sand	40.8	52.3
50% PGBS + 50% Crusher Dust	30.9	49.7

Slag Sand preparation unit at JSW Vijayanagar Works

First of its kind in the country



Advantages

- •Environmental friendly alternative.
- •Controlled Physical and Chemical Properties.
- •No deleterious material.
- •Available through out the year.
- •Graded products to meet specific needs.
- •Suitable for Roads, Concrete, Plaster, Mortars, RMC Plants etc.

Can be used in ……

- •Plain Concrete
- •Reinforced Concrete
- •Standard Ready-Mix Concrete
- •Dry Lean Concrete
- •Pavement Quality Concrete
- •Rapid-setting Concrete
- •Asphalt Concrete

Recognitions

Slag is best alte
to river sand:

Times News Network

Mysuru: Granulated blast furnace slag is the best alternative to river sand, said Mohan Rao Kunte, a member of Builders' Association of India. Mysuru district requires 2.23 million tonnes of sand every year. But river sand has become scarce following a ban on sand mining and its transportation.

"Karnataka requires nearly 20 million tonnes of sand every year. But we are getting only 9 million tonnes. Of the available sand, 4 million tonnes is used by the public works department, leaving only 5 million tonnes for the public whose actual requirement is 16 million tonnes," he said, and added: "The best way to meet the demand is using granulated blast furnace slag which is produced from slag formed during the production of steel."

About 30% of raw materials used in steel production gets converted into slag, and this can be used for construction purposes. Already, PWD has ordered the use of slag for road works. Besides being the best alternative to river sand, slag is also cheaper. The per-cubic-feet price of river sand and slag is in the range of Rs 100-120 and Rs 60-70," Kunte claimed. He also said that some experts had been to Kozhikode to study how slag is used as an alternative to river sand. Due to the lack of river sand, a majority of the construction works, including high rise buildings in Kozhikode, had made use of slag. In Mysuru too, many have started using slag.

DEMAND VS SUPPLY: According
requires nearly 20 million tonnes
been getting only 9 million tonne
lion tonnes is used by the public
5 million tonnes for the public

THE HIN

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Slag sand vs. river sand

NEMMANI SRIDHAR

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Slag sand must become cheaper and more easily available t construction

With indiscrimi
riparian ecology
community has
alternatives to r

Some of the opt
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DECCAN Chronicle

NATION, CURRENT AFFAIRS

Slag for river sand? JSW does it at Ballari

DECCAN CHRONICLE | SHIVAKUMAR G. MALAGI

Published Jul 28, 2015, 12:06 pm IST Updated Jan 10, 2016, 8:38 am IST

JSW Steel Ltd has installed a special slag sand preparation unit at its premises in Toranagallu

Ballari: To cater to the increasing demand and quality requirements, steel major JSW Steel Ltd has installed a special slag sand preparation unit at its premises in Toranagallu here.

According to JSW authorities, slag is an eco-friendly material obtained as a residue of the industrial process which can replace river sand in the construction of buildings. JSW Steel is the first steel plant in the country to use slag sand. Forest minister Ramanath Rai who inaugurated the unit said, "Slag sand as an alternative to river sand will protect river banks and save the environment. It will also help curb the river sand mafia's influence".

Dr. Vinod Nowal, deputy managing director, JSW Steel said, "Slag sand has the tenacity to replace river sand as a building material, this will lead to a better environment." JSW authorities said

Applications at JSW Steel

Foundation, Flooring and Roads at CRM-II Complex

Roads at SMS-III

Paver blocks at Township

Plastering at BRM-II

Usage at JSW – Project site

FLOORINGS FOR HEAVY LOADS

Usage in nearby areas

CSR Activities - Concrete Village Roads

Roads & Canteen Building at ACC Kudtini

Pavements / Roads at Ozone Urbana Bangalore

Plaster application with Slag sand in Building works

Location: Nirmiti Kendra Administrative Office Building, Bellary

Slag sand stock pile at work location

Plastering work on ceiling in the new office building of Nirmiti Kendra

Discussion and Interaction with government Civil Engineers by JSW staff

Usage in Roads

KPCL-Sultanpur Road, Bellary

Laying of GSB Using GLDS

Laying of DLC

Used in all three Layers

PQC – Pavement Quality Concrete

DLC –Dry lean Concrete

GSB – Granular Sub-Base

Constructed Road Portion – Capable of taking heavy loads



Blast Furnace Slag sand used in village roads

Jumanal village, Bijapur district, Karnataka

by

Karnataka Rural Infrastructure Limited (KRIDL)

Hospet-Bellary- (NH-63)




- Gammon Utilizing slag in GSB, DLC and PQC
- First time in India - a complete slag based road

BIS – IS-383 Amendment

2nd - Revision	3rd - Revision

2nd - Revision

IS : 383 - 1970

1. SCOPE

1.1 This standard covers the requirements for aggregates, crushed or uncrushed, derived from natural sources, such as river terraces and river-beds, glacial deposits, rocks, boulders and gravels, for use in the production of concrete for normal structural purposes including mass concrete works.

3rd - Revision

Indian Standard

COARSE AND FINE AGGREGATES FOR CONCRETE - SPECIFICATION

(*Third Revision* of IS 383)

ICS No.: 91.100.30

Cement and Concrete Sectional Committee, CED 2 — Last Date for Comments: **15 May 2015**

1 SCOPE

This standard covers the requirements for aggregates, crushed or uncrushed, derived from natural sources, such as river terraces and riverbeds, glacial deposits, rocks, boulders and gravels, and manufactured aggregates produced from other than natural sources, for use in the production of concrete for normal structural purposes including mass concrete works.

Environmental Friendly Aggregate

- **Slag is non hazardous, non toxic.**
- **Slag is free of any impurities like silt clay etc**
- **Used extensively for civil/road construction in developed countries**
- **Slag sand, if used can stop mining of river sand**
- **Consider slag sand as a Green Material**

Pricing

- Processed – Rs 525 + (GST – 5%) → Rs 551 Ex works
- Un - Processed – Rs 350 + (GST – 5%) → Rs 368 Ex works
- +80 Customers/Traders

Thanks ....

CRUSHED STONE SAND, PLASTER SAND AND LATEST REVISION IN IS 383-2016

By
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INTRODUCTION:

The process of forming natural sand has occurred over billion of years and as they were exploited, they are not replenished at the rate they are being used. Fine aggregate is one of the important constituents of concrete. 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 of our country from total death. As natural sand deposits become depleted near some areas of metropolitan growth, the use crushed stone sands as a replacement fine aggregate in concrete is popularly increasing. Designers, specifiers, contractors and material suppliers need to understand the effects of crushed stone sand characteristics on concrete water demand and concrete durability.

AGGREGATE TECHNOLOGY:

The term "Aggregate Technology" may be used for a combined use and interaction of the three essential fields of knowledge necessary in order to exploit, manufacture and use a mineral aggregate for construction purpose.

The basic interdependent principles of "Aggregate technology" are following:

1. Material Technology which deals with use of aggregates.
2. Production Technology which deals with the processing of aggregates.
3. Knowledge of Geology which is essential to source the aggregates.

Construction aggregate, or simply "aggregate", is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined materials in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material.

The characteristics of the geological material – mineral composition, structure and texture, crystal size, alterations, and for a sand/gravel; the particle shape, grading and surface properties – will be determinant both for product materials properties and for the choice of manufacturing processes. There is interdependency between geology and production technology, as one and the same manufacturing process will not be suitable independently of the rock type and the quarry setting. Similarly, an optimum e.g. concrete proportioning will have to be adapted to the aggregate characteristics, given partly by the geological parameters, partly by the parameters determined from processing. And finally – the other way around – the requirements to the end product will often be decisive for the choice of the geological raw material as well as for the production process to be designed.

CLASSIFICATION OF FINE AGGREGATE AS PER LATEST REVISED IS 383-2016:

Latest revision has been formulated to cover requirements for aggregates derived (both fine and coarse) from natural resources and other natural resources, for use in concrete. As per the revised standard fine aggregates are classified as follows:

1. Natural sand
2. Crushed sand
3. Mixed sand
4. Manufactured sand

Natural Sand: Fine aggregate resulting from the natural disintegration of rock and which has been deposited by flowing rivers and streams. This is also termed as uncrushed sand.

Crushed Sand: Fine aggregate produced by crushing hard stone is called as "Crushed stone sand". Crushed stone sand is popularly known by several names such as Crushed sand, Rock sand, Green sand, Robo sand, Poabs sand, Barmac sand, Pozzolan sand. Fine aggregate produced by natural gravel is called as "Crushed gravel sand".

Mixed Sand: Fine aggregate produced by blending natural sand and crushed stone sand or crushed gravel sand in suitable proportions.

Manufactured fine aggregate (Manufactured sand): Fine aggregates manufactured from other than natural sources, by processing materials, using thermal or other processes such as separation, washing, crushing a d scrubbing. Recycled concrete aggregate is also a type of manufactured aggregate.

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.

Crushing

Manufactured Sand is produced by feeding hard stones of varying sizes to primary and secondary crushers (Jaw crusher and Cone crusher), for size reduction and these crushed stones are further crushed in Vertical Shaft Impact (VSI) crusher to reduce the particle size to that of sand. The VSI crusher by its unique design and action of attrition produces well shaped fine aggregate particles that are cubical and angular. The process of attrition also enables the reduction of surface roughness of the fine aggregate particles to some extent.

The fine particles obtained, as a by-product during crushing of rocks to produce coarse aggregates (by jaw crusher and/or cone crusher) is known as Crusher Dust/Quarry Dust. This often contains higher percentage of dusty, flaky particles and particle sizes are un-controlled. This is not suitable for construction, as they result in higher water demand leading to lack of control on workability / retention of workability as well as strength issues.

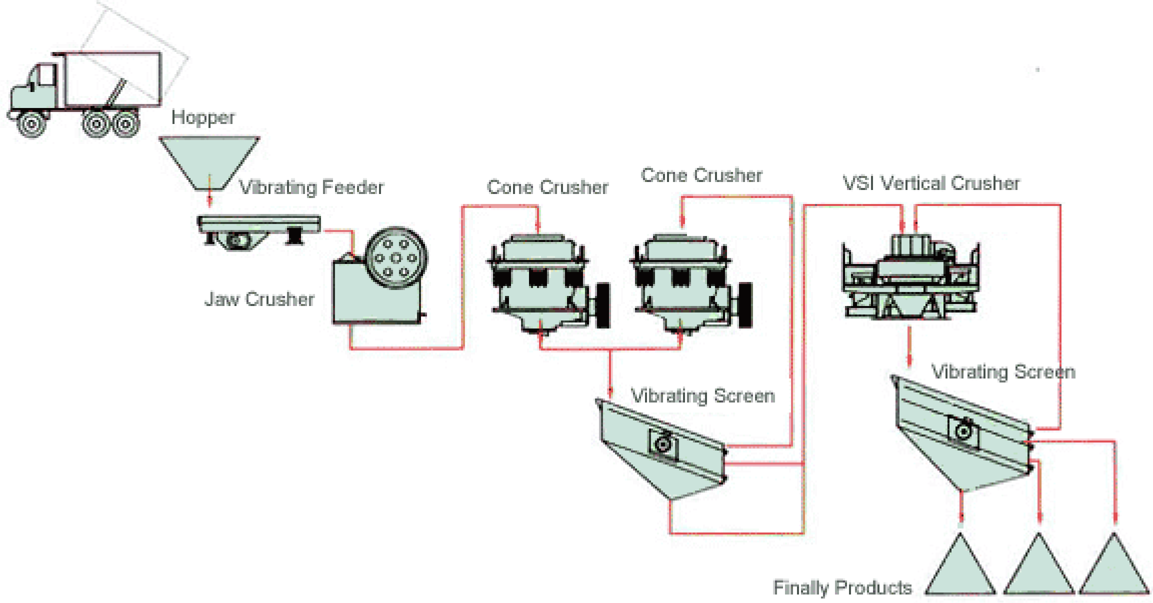

Fig.1 Aggregate Crusher Flow Diagram

Screening and Washing

With built-in process of different stages of screening, Manufactured Sand plants ensure proper grading for better particle size distribution. By washing, the percentage of micro fines (passing 75 micron) is controlled below 15% by weight. The washing facility also provides keeps the Crushed Stone Sand in wet or partially wet condition. This will help to reduce the water absorption rate by Sand during concrete manufacturing and hence better workability and workability retention.

Air Classifying:

Traditionally removing filler has been done by wet classifying, but this has been at substantial cost to the quarry operator. Dry processing is now developing into a cost effective and value-adding alternative. The move away from wet classification has been driven by the need to reduce operation and maintenance costs associated with these activities. Sourcing of water to operate these plants is becoming increasingly difficult. The treatment and reclamation costs of sedimentation ponds have been an expensive but necessary activity. By reducing these costs operators can reduce site costs. Dry classification of filler is generally done using air. This involves moving air

currents through free falling manufactured sand. The lightweight particles are effectively removed
and transported to an independent separation stage. The filler can then be classified as either a general-purpose product or, as some innovative customer's are doing, treating this material and selling it in new and exciting industry applications.

CHARACTERISATION AND TESTING:

Test Methods

There are many various test methods presented in order to classify the various properties of manufactured aggregates and fines.

Characterisation of Rock as Raw Material

Petrographic description is a technique to express the mineral content of an aggregate.

Characterisation and Testing of Sand and Fines

One of the problems in dealing with manufactured sands is the lack of a set of tests that fully characterize the three main properties of the individual particles. The properties, that should be characterized are:

1. Particle shape,
2. Particle size,
3. Particle surface texture.

It is not only necessity to know these individual properties of the aggregates, it is also important to know how these properties influence the concrete in both its hardened and plastic states. It is also desirable to understand how the properties of each of the aggregate sizes, or material types, impacts on the entire aggregate blend.

Photographs showing heap of Crushed Stone sand and close up of view exhibiting the shape, size of the material.

QUALITY TESTS AND ACCEPTANCE CRITERIA

One of the, major contributing factors to the quality of concrete is the quality of aggregates used therein. Various test methods are adopted to assist in assessing the quality of aggregates. In a given situation, for a particular aggregate, it may not be necessary to -assess all the qualities and therefore it is necessary to determine beforehand the purpose for which a concrete is being used and the qualities of the aggregate which require to be assessed. Accordingly, the relevant test methods may be chosen from amongst the various tests.

In order to accept or otherwise all relevant quality tests stipulated in Bureau of Indian Standards IS 383-2016 shall be conducted. Theses quality tests are covered on various parts of IS 2386 – 1963 and other related IS standards and standard publications. Fine aggregates are mainly used for following purposes:

1. Concrete making
2. Plastering
3. Masonry mortar.
4. Filter media and as a base for tile laying

QUALITY TESTS: Following are the quality tests conducted on fine aggregates for the purposes mentioned above.

Concrete making:

1. Sieve Analysis
2. Specific Gravity and Water absorption.
3. Bulk Density (Loose & Rodded)
4. Bulking
5. Organic Impurities
6. Deleterious Materials- Coal & Lignite, Clay Lump, Materials Finer Than 75 Micron, Soft Fragments, Shale
7. Soundness (Chemical Test)
8. Alkali-Silica Reaction Test (ASR)
9. Petrographic examination

Acceptance criteria for Sieve analysis: The grading of fine aggregate, when determined as described in IS 2386 (Part 1) shall be within the limits given in Table 1 and shall be described as fine aggregate, Grading Zones I, II, III and IV. Where the grading falls outside the limits of any particular grading zone of sieves other than 600 µm 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 µm 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 1 GRADING LIMITS FOR FINE AGGREGATES IS:383-2016

IS SIEVE	***PERCENTAGE PASSING FOR***			
	ZONE 1	**ZONE 2**	**ZONE 3**	**ZONE 4**
10.00 mm	**100**	**100**	**100**	**100**
4.75	**90-100**	**90-100**	**90-100**	**95-100**
2.36	**60-95**	**75-100**	**85-100**	**95-100**

1.18	**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 **Natural River Sand** **Crushed Stone Sand**	 **0-10** **0-20**	 **0-10** **0-20**	 **0-10** **0-20**	 **0-15** **0-20**

NOTES

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

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.

3. 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.

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.

TABLE SHOWING CHARACTERISTICS OF CRUSHED STONE SAND (TYPICAL)

Sl.No.	Parameter tested	Test results	Specification as per IS 383-2016
1.	Dry rodded bulk density	1963 kg/cu.m	-
2.	Loose bulk density	1769 kg/cu.m.	-
3.	Specific gravity	2.62	-
4.	Materials finer than 75µm IS Sieve	13.5%	15% (Maximum)
5.	Coal & Lignite	Nil	1.0 % (Maximum)

6.	Clay lumps	Nil		1.0 % (Maximum)
7.	Soundness	1.2% (tested with sodium sulphate) 1.3% (tested with magnesium sulphate)		10 % (Maximum) 15 % (Maximum)
8.	Sieve Analysis			
IS Sieve Designation		Cumulative Percentage		For Zone II (Percentage Passing)
		Retained	Passing	
4.75 mm		0.1	99.1	90-100
2.36 mm		19.6	80.4	75-100
1.18 mm		37.9	62.1	55-90
600 µm		54.4	45.6	35-59
300 µm		83.2	16.8	8-30
150 µm		91.0	09.0	0-20

Geological, Mineralogical & Petrographic Issues

The raw material for production of crushed sand is the parent mass of rock. Thus, many aggregate properties depend on the properties of the parent rock (e.g., chemical and mineralogical composition, petrographic classification, texture, surface properties, alterations, specific gravity, hardness, strength, physical and chemical stability, pore structure and colour). Mineralogy and petrography can be quantified in order to estimate the quality of aggregates in exploration procedure, and to assess and verify the quality of subsequent test results.

Among the well- known relations is the negative influence of free mica for the water requirement in concrete – and also that this is more detrimental for crushed sand than for natural sand, where the surface properties of the mica minerals have been altered during thousands of years' natural weathering. Free mica negatively influences microstructure and the physical properties of mortar and concrete.

NEW ZEALAND FLOW CONE TEST

To evaluate a sand or a blend of sand, the NZ Flow Cone test (NZS 3111 Section 19) is used to measure flow and void properties. It is widely used within New Zealand and, to a lesser extent, in other countries as a measure of sand characteristics. The test involves passing a determined mass of sand through a cone into a receiver. The time taken for the sand to pass is recorded. The receiver into which the sand is poured is leveled off, weighed and the percentage voids are then calculated. The resultant voids content and flow time is plotted and from this an indication of a sand's performance can be determined.

PHOTOGRAPH : Newzealand Flow Cone

The flow time of a sand is a function of grading, particle shape and texture.

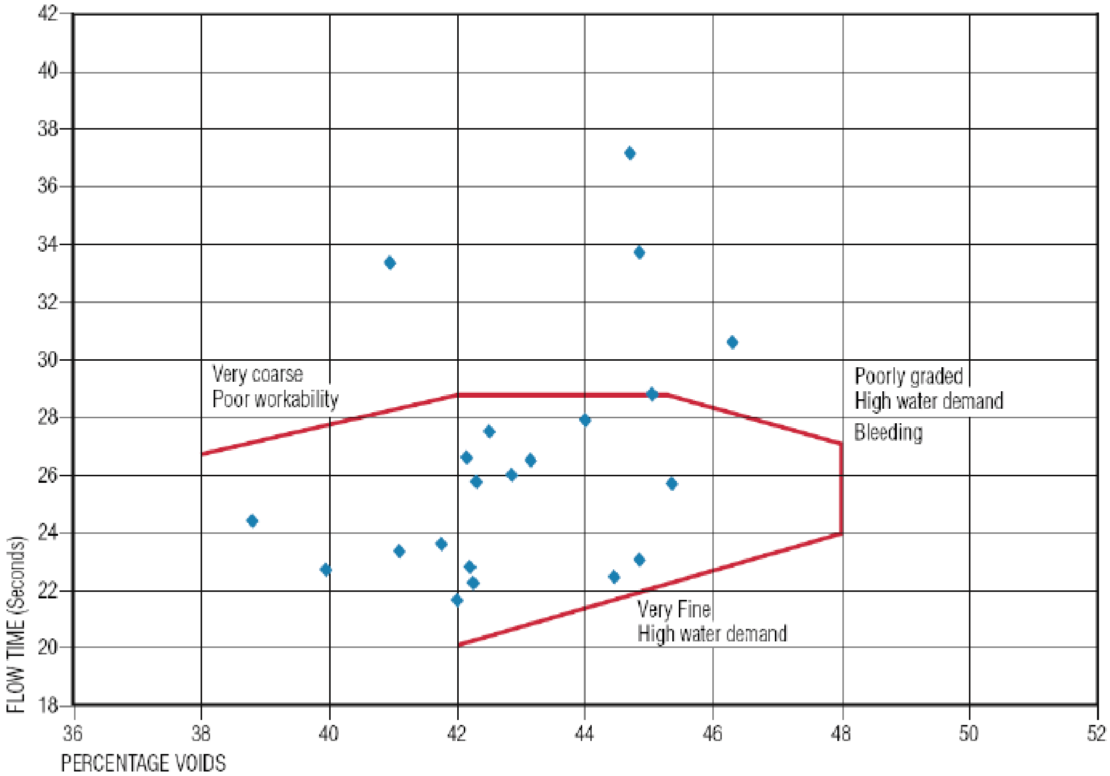

FIGURE 2- The red line differentiates the sands that are suitable and not suitable to be used in normal concretes. Dots lying outside the line are considered unsuitable because; they produced harsh concrete or their water demand was excessive (Cement, Concrete & Aggregates – Australia, 2007)

CONCRETE MIXES PROPORTIONED USING CRUSHED STONE SAND:

Concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available. In hardened state concrete shall have required strength, durability and surface finish.

TYPICAL MIX PROPORTIONS FOR PUMPING CONCRETE USING MANUFACTURED SAND

Mix Design -ation	Aggr. Max. size (mm)	Suggested Mix Proportions C:FA:CA**	Water Cement ratio (max)	Slump Obtained (mm)	Cement Content* (Kg/cu.m)	Dosage of admixture per bag of cement+	Compressive strength (N/sq.mm) 7days	28 days
M25	20	1 : 2.18: 3.78	0.50	90	320	600 ml	23.8.	33.0
M30	20	1 : 2.00: 3.47	0.50	100	340	550 ml	27.5	40.0
M35	20	1 : 1.71: 2.98	0.44	100	380	600 ml	30.6	45.0
M40	20	1 : 1.75: 2.83	0.41	100	400	650 ml	34.9	50.5
M45	20	1 :1.56: 2.62	0.40	100	420	600 ml	44.7	55.6
M50	20	1 :1.48:2.60	0.34	90	450	600 ml	45.2	65.0
M55	20	1 : 1.48: 2.55	0.34##	100	450#	600 ml	50.2	68.0
M60	20	1 : 1.38 :2.32	0.34	100	475#	600 ml	54.2	69.9

* This has to be verified at site.
\# Cementitious material content (Cement and Microsilica shall be added as 425 & 25 kg/cu.m respectively for M55 grade, 450 & 25kg/cu.m for M 60 Grade)
\## Water/Cementitious ratio
\+ Admixture used is Super .
** Cement : Fine Aggregate : Coarse Aggregate

CRUSHED STONE SAND FOR PLASTERING WORKS:

The performance of a building depends to a great extent on the quality of the plaster. Plasters are the decoration and protection of a building. In recent times, scarcity of Natural River Sand has resulted in search for alternatives for both Concrete making as well as Plastering.

CHARACTERISATION OF PLASTERING SAND

i) Physical Tests

a) Sieve analysis
b) Specific Gravity
c) Bulk density
d) Material finer than 75 microns
e) Clay lumps

ii) Chemical Tests

a) Light weight pieces
b) Organic Impurities

GRADATION REQUIREMENTS OF SAND FOR PLASTERING WORKS

IS Sieve Designation	Requirement of Sand for Plastering as per Specification IS:1542 -1992 (RA 2003)
10.00 mm	100
04.75 mm	95 - 100
02.36 mm	95 - 100
01.18 mm	90 - 100
600 microns	80 - 100
300 microns	20 - 65
150 microns	0 -15

Sl, No.	Test Conducted	Requirement of Sand for Plastering as per Specification IS:1542 -1992 (RA 2003)
1	Clay lumps (%)	Clay, Silt and Dust not more than 5%
2	Material finer than 75 microns (%)	Not Specified
3	Specific gravity	Not Specified
4	Bulk Density (kg/lit) Loose Rodded	Not Specified
5	Light weight pieces (%)	Not Specified
6	Organic Impurities	The aggregate shall not contain harmful organic impurities in sufficient quantities to effect adversely the strength or durability of concrete.

CONCLUSIONS:

Cconcrete industry has been using high fines “Crushed Stone Sand” in concrete mixes for more than 30 years. Experience and practice has demonstrated that not only crushed stone sand be used successfully as a substitute for natural river sand , but also in many cases it will have superior performance.

Understanding not only the effect of grading, but also shape and surface texture on fine aggregate performance in concrete is the key to successful use. Their particle size distribution helps in higher packing density which enhances the durability of concrete.

Some past experience of manufactured sand has been negative due to incorrect processing and proportioning of sand in the concrete mix. However, if the material is treated correctly it will perform well in both fresh and hardened concrete and mortar.

<u>REFERENCES</u>

(1) IS 10262- 2009 : Concrete Mix Proportioning-Guidelines (First Revision)

(2) IS 383 – 2016 : Indian Standard specifications for : coarse and fine aggregates from natural sources for concrete.

(3) IS:456-2000 : Code of Practice for Plain and Reinforced Concrete.

(4) IS 4926-2003 : Ready-mixed concrete-Code of Practice

(5) Neville A. M. (1995). “Properties of Concrete,” Longman, 4th edition

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POND ASH in Concrete

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R T P S PONDASH - 3

R T P S PONDASH - 4

Solution

- Utilise Pond Ash by various means
  - ➢Land Fill
  - ➢Embankments
  - ➢In construction Industry
    - ✓In Concrete
    - ✓In Mortar

❑ **Possibility of Utilising Pond Ash as a replacement to Cement and/or Fine Aggregate**

POND ASH

Characterization

- Sample collection
- Sample designation
  - – P1, P2, P3 and P4.
- Guideline to carry out physical and chemical analysis
  - – IS: 1727-1967 followed (Since a separate Indian code for Pond ash is not available)

Physical properties studied

- Specific Gravity
- Fineness
- Initial Setting Time
- Final Setting Time
- Soundness
- Lime Reactivity and
- Compressive Strength

POND ASH

Chemical analysis

Determination of:

- Loss on Ignition
- Total silica
- Alumina
- Iron oxide
- Calcium Oxide
- MgO
- Sulphuric unhydride
- Insoluble residue and
- Soluble salts

XRD and SEM studies were also carried out on these samples.

POND ASH- Physical Properties

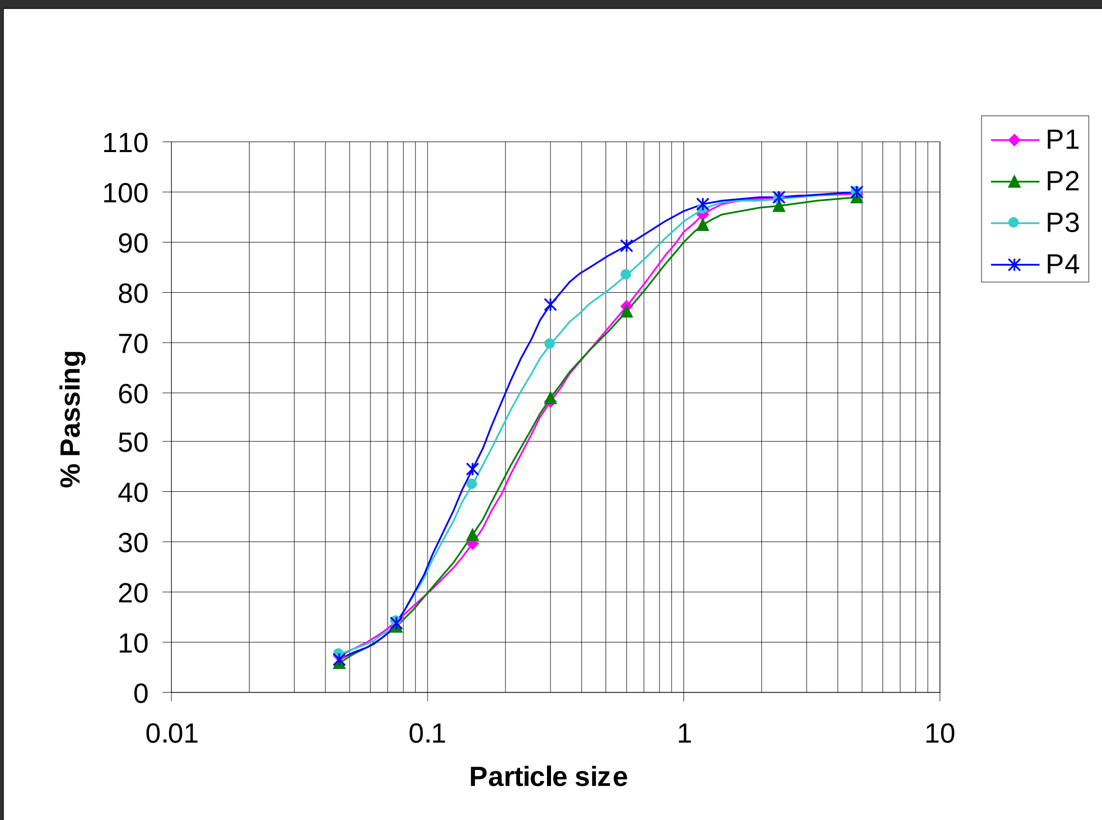
Sieve analysis

Sieve Size (m m)	% 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

Wet sieving of P A sample

POND ASH- Physical Properties

Particle Size Distribution



Observations

- percentage passing for all the samples comparable with grading limits of the zone IV of IS:383.
- average value of fineness modulus of PA around 2 (average size of the particle around 300 microns).

POND ASH- Physical Properties

Specific Gravity

Sample	Specific gravity
P1	2.47
P2	2.33
P3	2.30
P4	2.25

- range from 2.25-2.47 - less than the specific gravity of sand.

POND ASH- Physical Properties

Lime Reactivity

Sample	% water	% Flow	Lime reactivity MPa
P1	20	66.7	0.69
P2	20	68.3	0.58
P3	20	65.0	0.66
P4	22	67.5	0.70

Values - significantly less than that for fly ash indication that the pond ash does not contribute to pozzolanic activity significantly

POND ASH- Physical Properties

Normal Consistency, Initial and Final setting time

Sample	Normal Consistency (%)	Initial Setting Time		Final Setting Time	
		Hours	Min	Hours	Min
P1	33	3	00	5	30
P2	33	3	10	5	35
P3	34	3	10	5	20
P4	34	3	00	5	20

Values higher than those for Normal Cement Mortar

POND ASH- Physical Properties

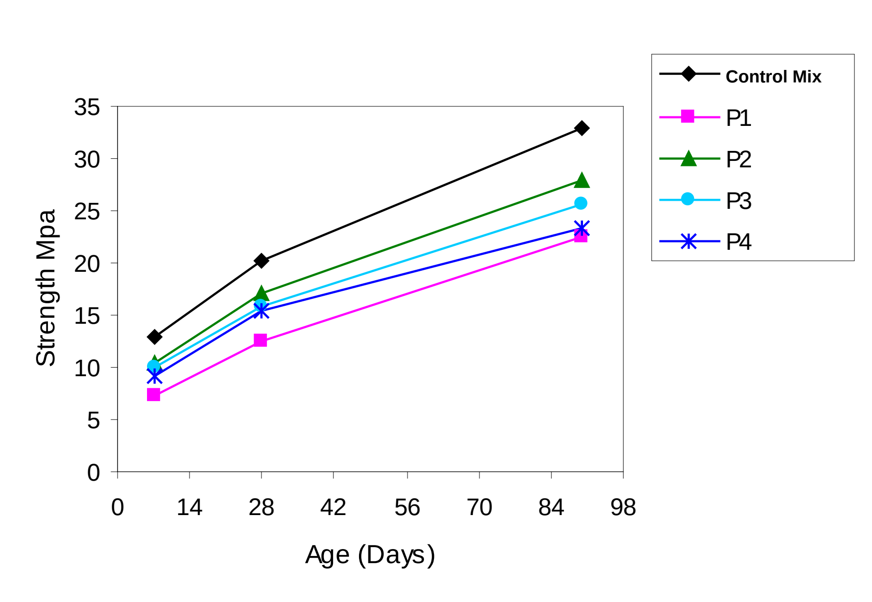
Compressive strength

Sample	7th Day Strength (Mpa)	%Change in Strength	28th Day Strength (Mpa)	%Change in Strength	90days Strength (Mpa)	%Change In Strength
Control cube	12.85	0.00	20.25	0.00	32.95	0.00
P1	7.36	42.72	12.57	37.9	22.42	31.96
P2	10.50	18.28	17.06	15.75	28.00	15.12
P3	10.04	21.87	15.79	22.02	25.66	22.12
P4	9.17	28.64	15.46	23.65	23.30	29.28

strength values of PA mortar cubes < control mortar cubes at all ages

POND ASH- Physical Properties

Variation of compressive strength of mortar with age



PA mortar cubes generally exhibit the same trend of increase in compressive strength with age.

POND ASH- Chemical Properties

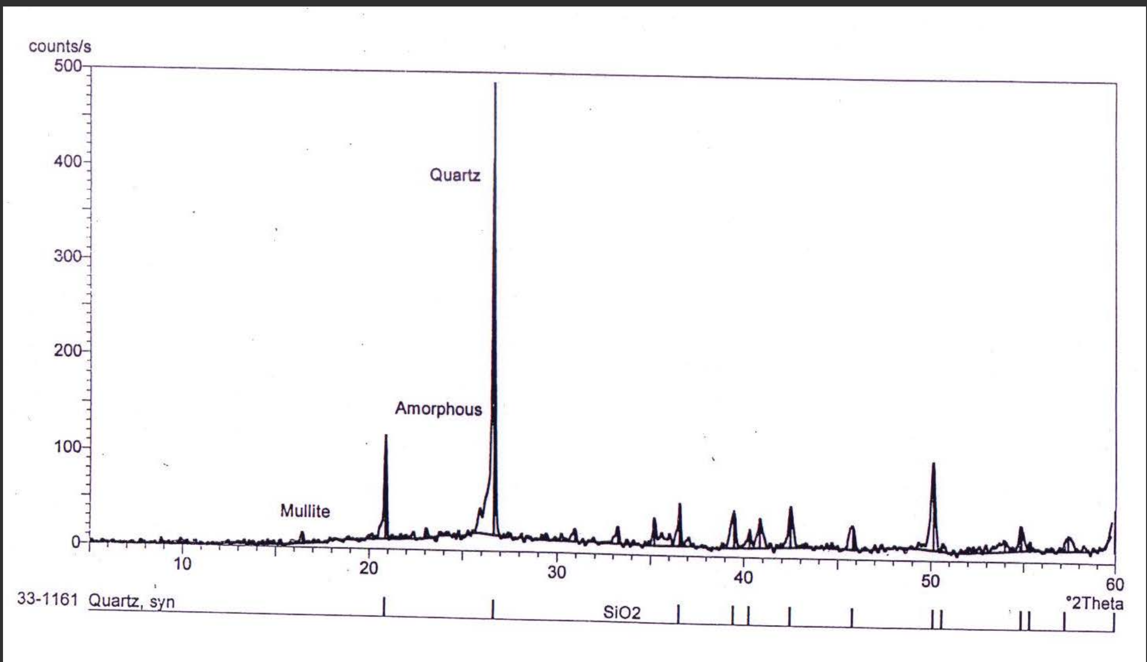
chemical analysis

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
Insoluble Residue (%)	89.90	90.60	90.30	91.50
Soluble Salts (%)	0.16	0.18	0.15	0.19

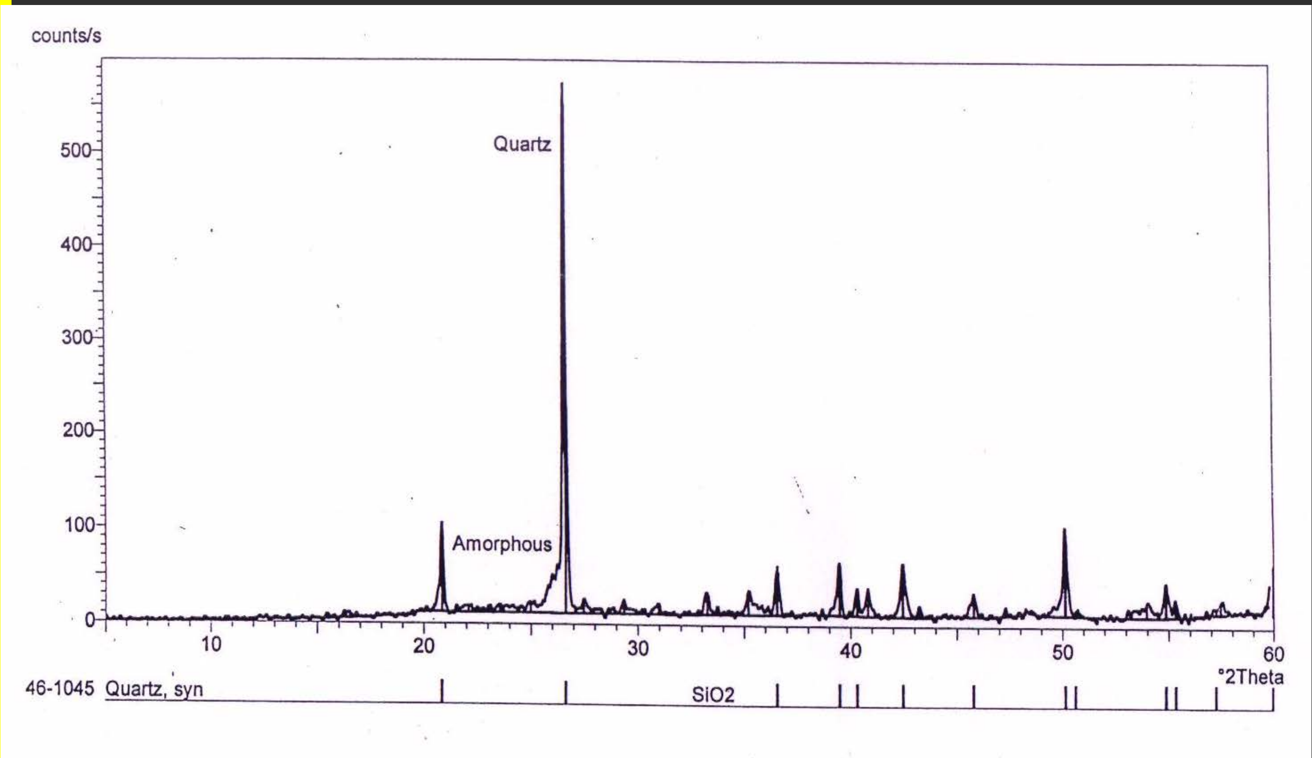
chemical composition of pond ash conforms to codal limits.

POND ASH- XRD Studies

XRD analysis carried out on representative samples of pond ash



XRD results of sample P2



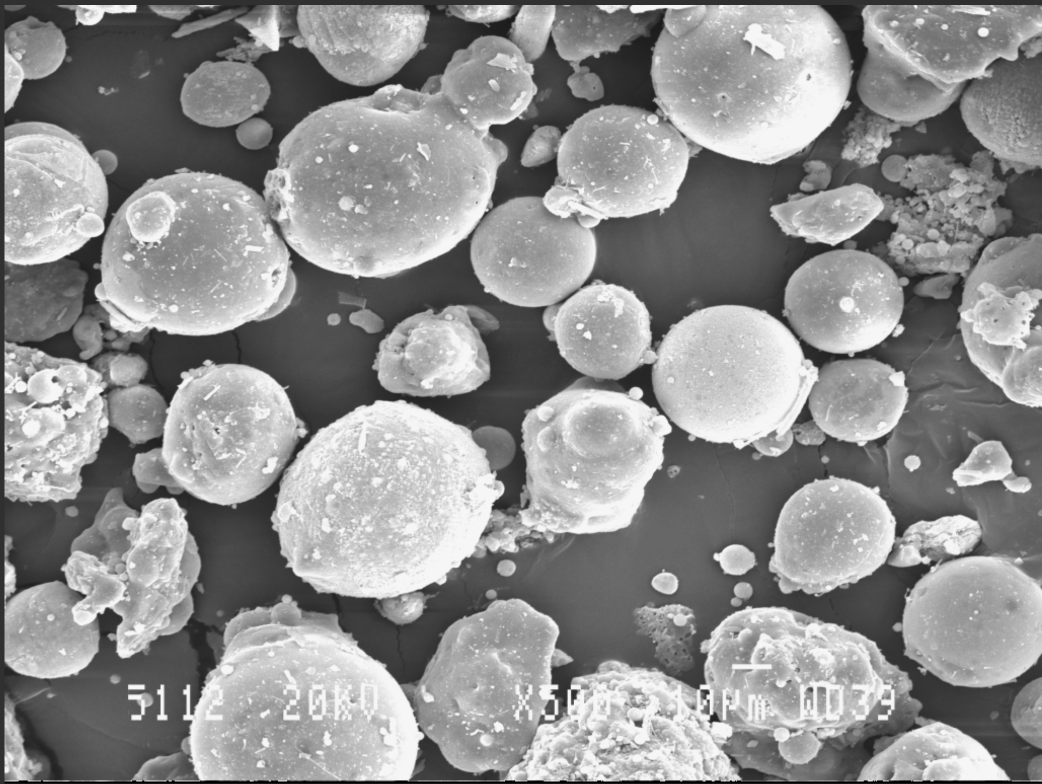
XRD results of sample P4

POND ASH- XRD Studies

Observations

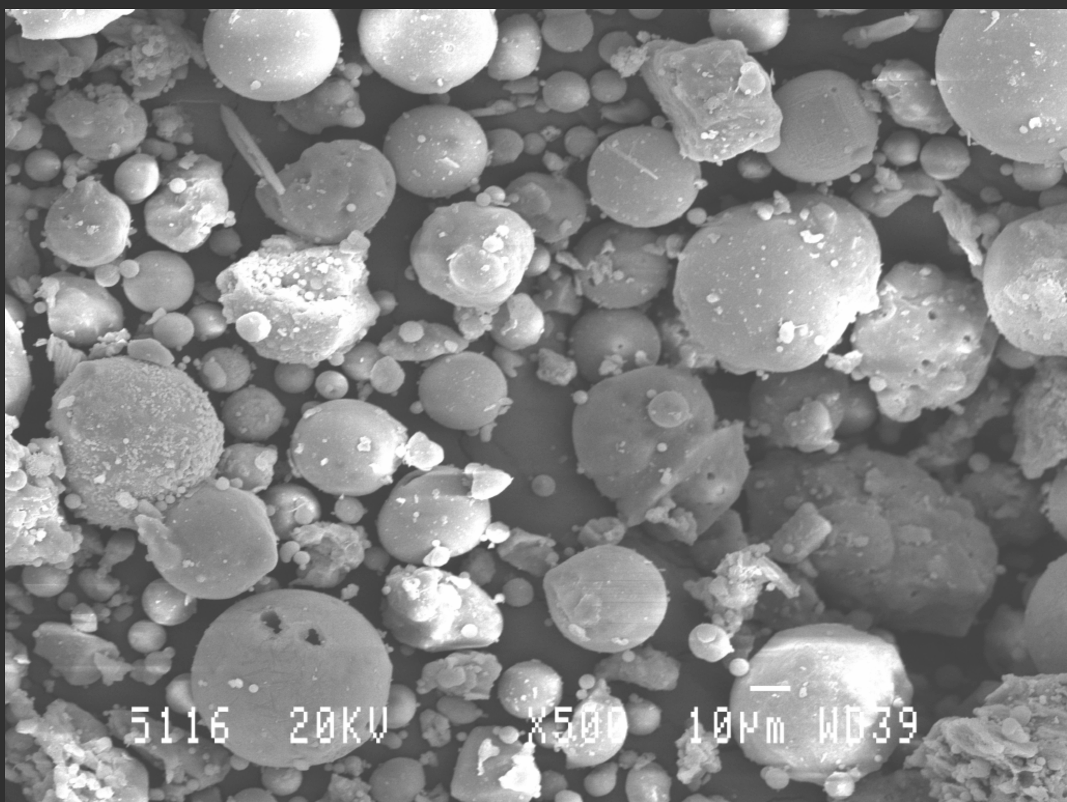
- predominant presence of Quartz (SiO_2) and smaller presence of Mullite ($Al_6Si_2O_{13}$)
- large peak heights (counts) indicating higher presence of crystalline particles
- base hump in the two pond ash samples small - indicate lesser pozzolanic behavior

POND ASH - SEM Studies



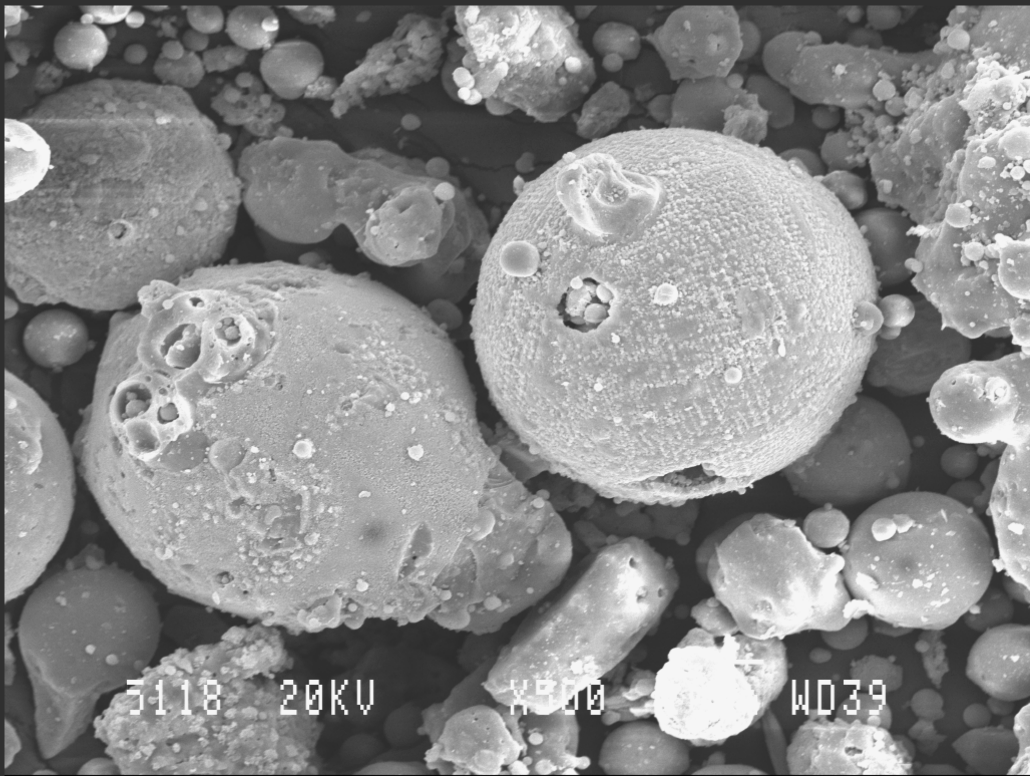
Sample P1 (1:500)

POND ASH - SEM Studies



Sample P2 (1:500)

POND ASH - SEM Studies



Sample P3 (1:500)

POND ASH - SEM Studies

Sample P4 (1:500)

Observations

- ✓ size of the particles ranges from 2µ to 150µ.
- ✓ Majority of the particles -in the range of 30 to 75µ
- ✓ Particles of size b/w 10 – 40µ are smooth and spherical
- ✓ At some locations sintered particles and surface depositions are observed.
- ✓ Irregularly shaped particles (which are relatively coarser) show a vesicular texture. These have probably undergone little or no fusion in the combustion process.
- ✓ In addition, large amount of lumped particles are present
- ✓ The presence of vesicular particles indicate that the pond ash consists of significant amount of bottom ash

Inferences from Characterisation

Based on the charaterisation studies carried out on pond ash obtained from RTPS, Raichur, the following inferences can be drawn.

- ❑ Pond Ash unsuitable to be used as partial replacement to cement
- ❑ Pond Ash can be tried as partial replacement of fine aggregate in concrete
  - - saving scarce natural resource like sand
  - - reduction of environmental pollution
- ❑ Possibility of small amount of pozzolanic activity **(as indicated by Lime reactivity and XRD tests)** - an added advantage incase of partial replacement of sand by pond ash.
- ❑ Presence of spherical particles (indicated by SEM studies) - possible increase in workability when pond ash is used as partial replacement of fine aggregate.

MIX PROPORTIONING BASED ON WORKABILITY

- Material specification
  - » Cement - 43grade OPC
  - » CA – Fineness Modulus - 6 (10mm)
  - » Sand - Fineness Modulus - 2.63 (b/w 0.6 & 0.3mm)
- M30 Concrete

Cement	Sand	C.A.	Water
330 kgs	864.18kgs	1100.82kgs	184.8ltrs

•M60 Concrete – S P – 2.5 %

Cement	Sand	C.A.	Water
430 kgs	763.60kgs	971.84kgs	172ltrs

MIX PROPORTIONING BASED ON WORKABILITY

Procedure followed

- ➢Proportion of CA & sand altered to obtain max Compaction factor
- ➢For this mix , sand replacement - 20, 30 & 40 % of P A
- ➢Further re-proportioned to obtain absolute Max workability
- ➢Concrete cubes were cast with this mix (M 30 & M 60) For strength & durability studies

Mix proportions and Compaction Factor

Mix	Batch Quantity Kg/Cum				
	Fine Aggregate	Pond ash	Coarse Aggregate	% CA in total aggregate	Compaction factor
CC3	825	0	1139	58	0.794
20PAC1	377	94	1493	76	0.822
30PAC1	330	141	1493	76	0.784
40PAC4	282	188	1493	76	0.780

M30 Grade Concrete, w/c = 0.50, Cement content = 330kg/m^3

Comparison of Compressive strength of Control concrete and Pond ash Concrete for M 30 grade concrete

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	40.6	-	53.6	-	58.0	-	60.1	-	57.6	-
20% Pond Ash	34.6	14.75 (D)	49.6	7.45 (D)	51. 3	11.50 (D)	55.0	4.61 (D)	55.6	3.47 (D)
30%Pond Ash	32.3	20.48 (D)	49.0	8.68 (D)	48.6	16.10 (D)	55.0	4.61 (D)	60.0	4.00 (I)
40%Pond Ash	34.0	16.37 (D)	44.6	16.77 (D)	47.6	17.81 (D)	52.3	9.24 (D)	58.6	1.73 (I)

(D) Indicates decrease in strength
(I) Indicates increase in strength

CONCRETE WITH POND ASH AS FINE AGGREGATE:

ils of cement content with
ent water cement ratios

Cement content kg/m^3	w/c ratio
350	0.69
	0.66
	0.63
	0.60
400	0.62
	0.59
	0.56
	0.53
450	0.5
	0.47
	0.44
	0.41

Proportion of pond ash and coarse aggregate 32: 68

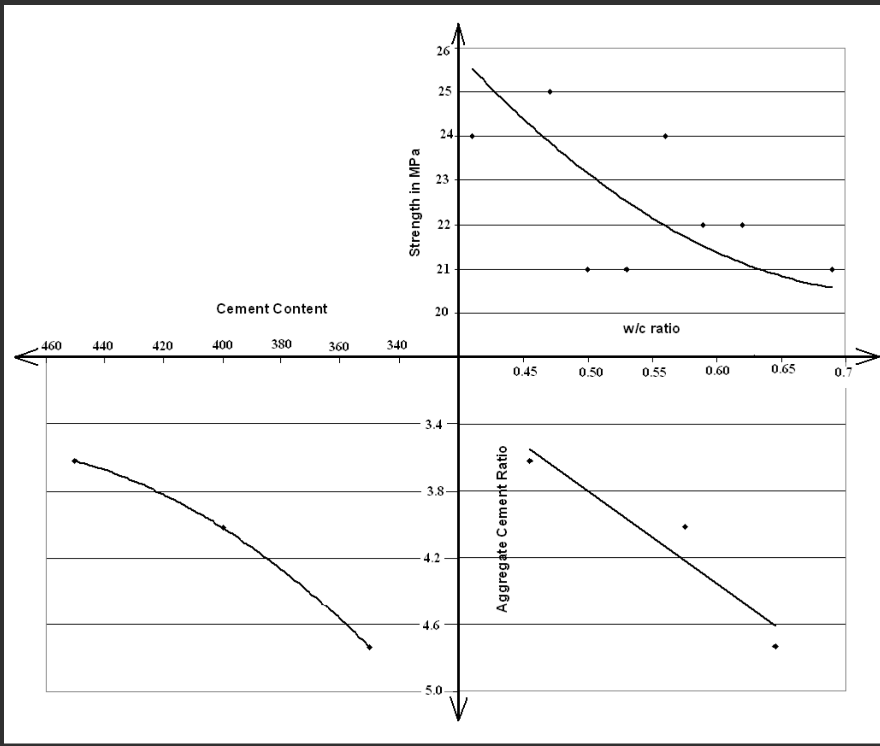
Sulphonated Naphthalene formaldehyde based super plasticizer to obtain required workability

Ingredients of different mix proportions

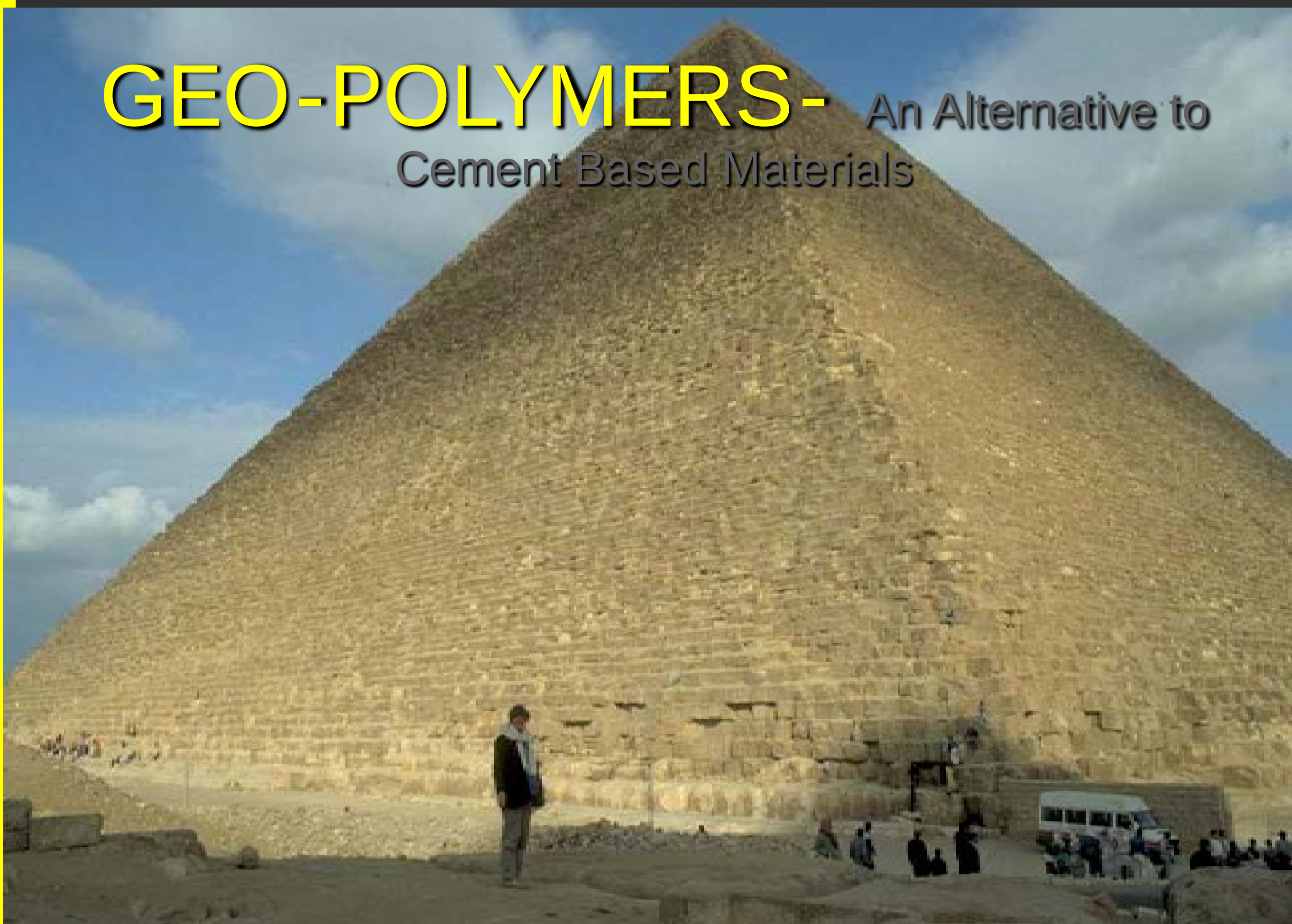
Cement Content kg/m³	Water Cement Ratio	Water Content kg/m³	Pond Ash kg/m³	Coarse Aggregate kg/m³	Vp	Va	Super Plasticizer Dosage lt/m3	Vee Bee time in seconds
350	0.69	242	518	1100	0.35	0.65	2	4
350	0.66	231	526	1118	0.34	0.66	4	5
350	0.63	221	535	1136	0.33	0.67	5	4.5
350	0.6	210	543	1154	0.32	0.68	9	6
400	0.62	248	500	1062	0.37	0.63	1	5
400	0.59	236	509	1083	0.36	0.64	3	5
400	0.56	224	519	1103	0.35	0.65	5	5.5
400	0.53	212	529	1123	0.34	0.66	9	5
450	0.5	225	506	1074	0.37	0.63	9	4
450	0.47	212	516	1097	0.35	0.65	17	5

Density and compressive strength values

Cement content	w/c ratio	Density kg/m³ at 28 days	Compressive Strength (MPa)		
			3rd day	7th day	28th day
350	0.69	21.34	10	13	21
350	0.66	21.79	11	16	24
350	0.63	21.53	11	14	19
350	0.60	21.97	10	13	17
400	0.62	22.28	11	15	22
400	0.59	22.37	12	15	22
400	0.56	22.44	13	16	24
400	0.53	21.86	13	15	21
450	0.50	22.52	12	15	21
450	0.47	22.58	13	18	25
450	0.44	22.07	14	18	27
450	0.41	22.77	13	18	24



Mix Design Nomogram (concrete with pond ash as fine aggregate)



RADICAL CHANGE IN CONCEPTS

(One typical case)

- ✓ ***Concrete with only Portland Cement***
- ✓ ***Concrete with Portland Pozzolana Cement***

  (With about 10 to 30% flyash in cement)
- ✓ ***Blended concretes with Pozzolana***

  (With about 10 to 30% flyash)
- ✓ ***High volume flyash concrete***

  (Blended with about 50 to 60% flyash)
- ✓ ***Geopolymeric concrete***

  (With 100% flyash and no Portland Cement)

Portland Cement and Geopolymer

- **Portland Cement → synthesis of high CaO minerals, main product is C-S-H gel from the hydration process; water is needed for the hydration process.**

- **Geopolymer → results of polymerisation process of minerals containing Si-Al; water is released during the chemical process.**

GEOPOLYMER CONCRETE

- Consists of aggregates with geopolymer as binder. The constituents include, silica rich base materials such as Fly ash/GGBFS, alkaline solutions and aggregates in designed proportions.

- "Green material", helps in reducing carbon dioxide emissions by replacing use of cement and also utilizes industrial byproducts.

MECHANISM OF GEOPOLYMERISATION

- ***One of the 'visualised mechanism' of Geopolymerisation' is***

Dissolution

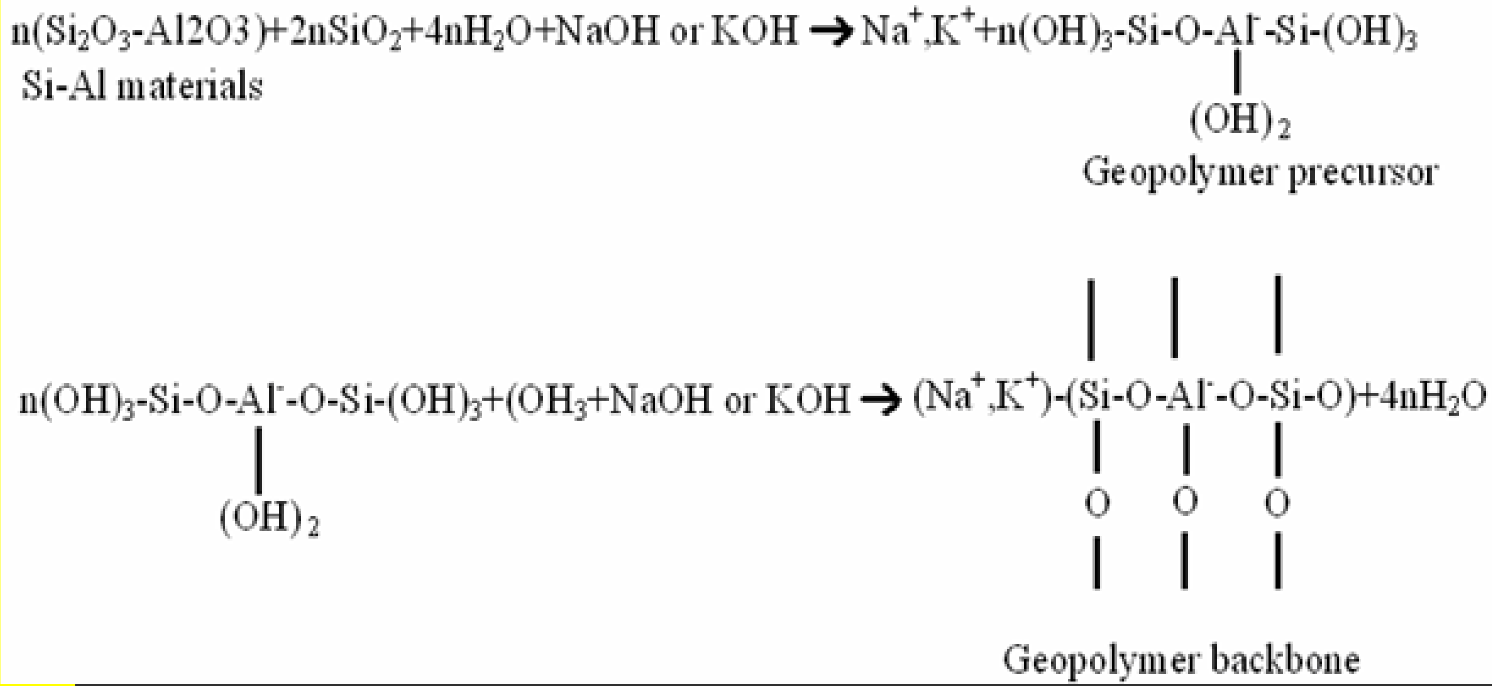
Gelation

Reorganisation

Polycondensation

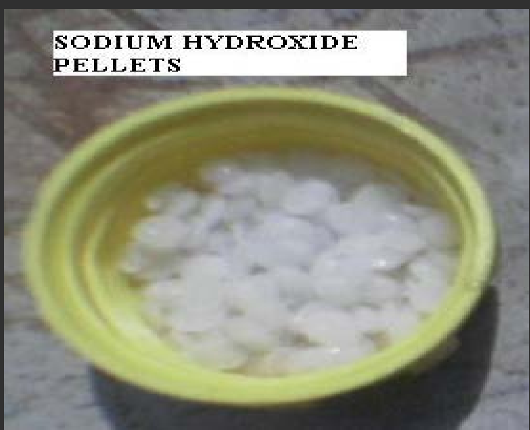
Reaction takes place through an exothermic process

Schematic Formation of Geopolymer



The rate of polymer formation is influenced by parameters such as curing temperature, alkali concentration, initial solids contents, etc.

***Alkaline liquid*: sodium hydroxide and sodium silicate solution, used as alkaline liquid.**



Sodium silicate(Gel form)

- ***Aggregates*: 12.5mm down size crushed granite aggregate, River sand Zone II**

Procedure Adopted:

- ***MIXING***:
  - *Dry material is mixed initially for 2-3 minutes , and then all the solution is added, mixing is continued for another 3-4 minutes.*

Sticky MIx

CURING OF GEOPOLYMER CONCRETE

Purpose of Curing is two fold –

a. To promote activation; and

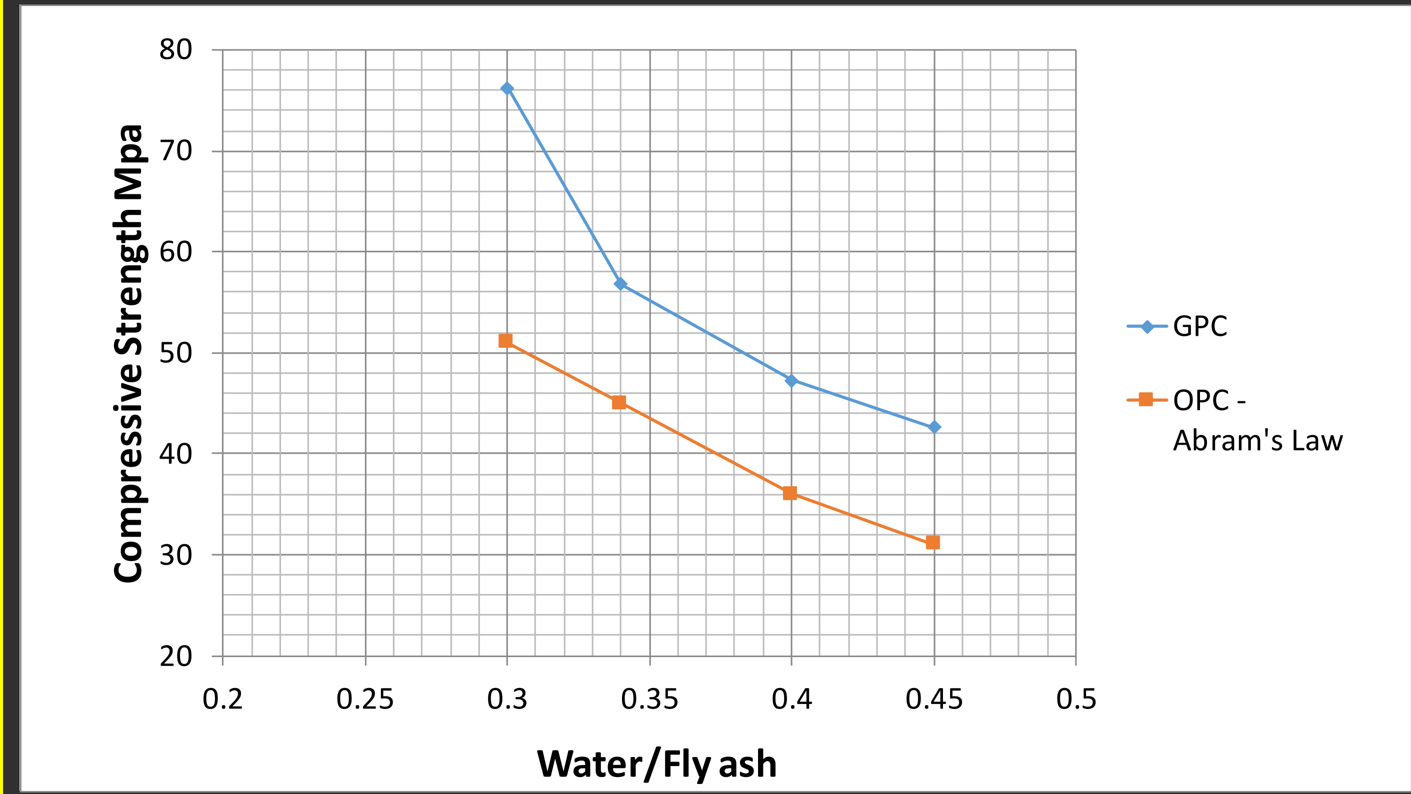
b. To preserve water in the mix, from the atmospheric hazards

Curing is generally carried out at elevated temperatures, in the range of 50 to 80 Deg C. Adequate humidity to be ensured or the product is to be insulated to preserve water in the mix

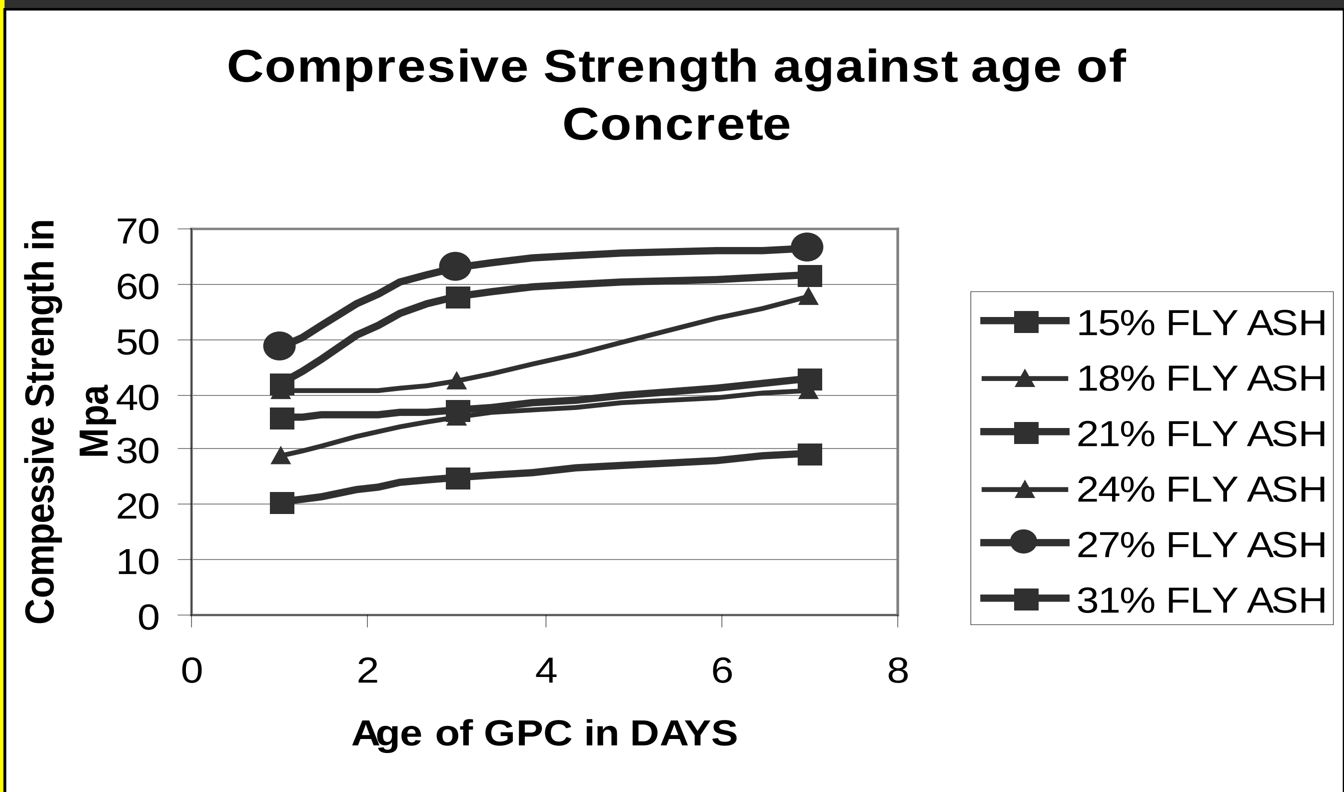
Contd/…

- Some Properties of Typical GPC Produced in Laboratories……

Comparison of OPC and GPC

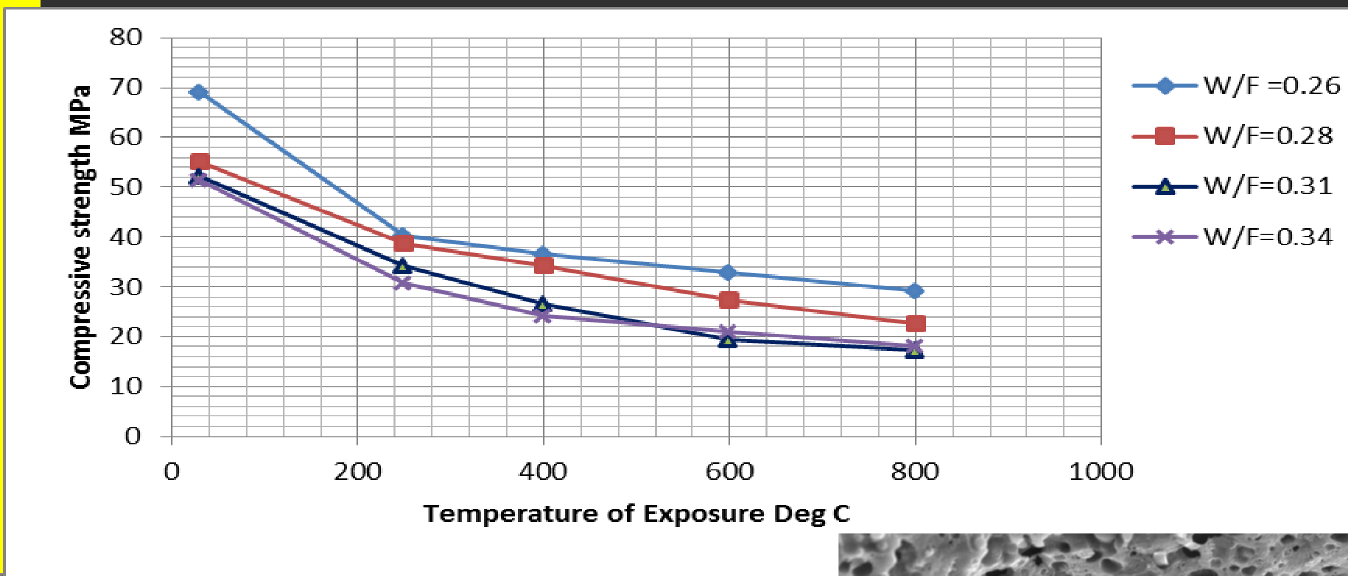


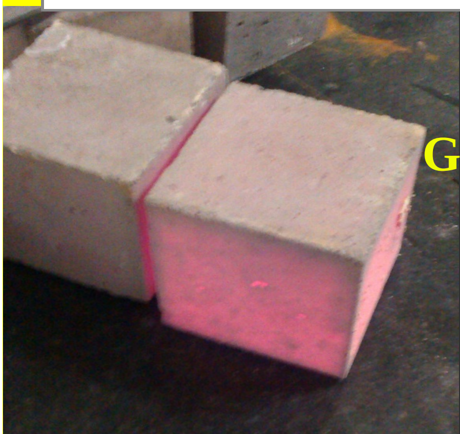
Compressive strength of GPC with Age



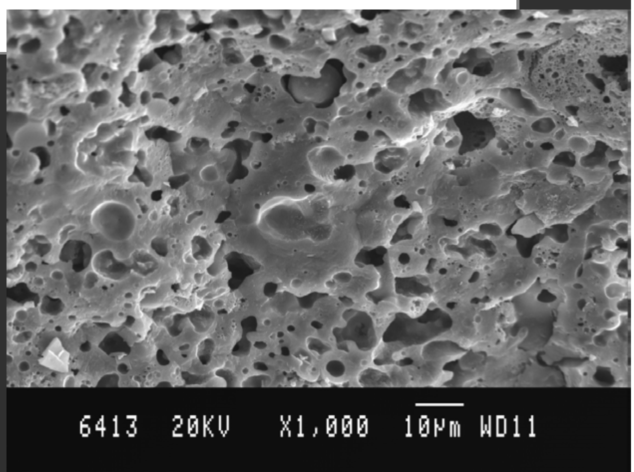
Durability Issues

- *Resistance to Elevated Temperature*
- *Sulphate Resistance*
- *Acid Resistance*





GPC EXPOSED TO ELEVATED TEMPERATURE



RESISTANCE TO ACID ATTACK

PRECAST BOX CULVERTS

[redacted]: Load testing of a 10 metre precast geopolymer beam.

2012

Composite pultruded girder and Grade 40 geopolymer deck bridge in Brisbane.

E-CRETE, ENVIRO CRETE, etc

UTILIZATION OF POND ASH AS FINE AGGREGATES IN GEOPOLYMER CONCRETE(GPC)

- Geo-polymer concrete prepared using pond ash as a replacement to natural fine aggregates.
- The replacement ranges from 20% to 100% of natural aggregates. Physical parameters of the resulting concrete are assessed by standard tests for compression, Flexure and Tensile stresses.
- The durability parameter is verified using the method of Water permeability test.
- The results obtained from the Pond ash Geo-polymer concrete is systematically analysed and compared with that of control mix i.e., normal Geo-polymer concrete.

Mix Calculation

Design Data

Wet density of Geopolymer concrete	$2400 kg/m^3$
Volume of the GPC	1
Molarity of NaOH	10 M
Percentage of water in Na_2SiO_3	40 %
Ratio of Na_2SiO_3/NaOH	2.5
Water content	165
Percentage of Base material	20 %
Specific Gravity of NaOH	1.47
Specific Gravity of Na_2SiO_3	1.56
Specific Gravity of CA	2.65
Specific Gravity of GGBFS	2.62
Specific gravity of pond ash	2.45

Mix design Table

Sl no	Replacement of fine aggregate	Fly ash	GGBFS	Fine aggregate	Pond ash	CA
1	0	330.16	82.53	660.2	0	990
2	20%			585.16	132.04	
3	40%			396.12	264.08	
4	60%			264.08	396.12	
5	80%			132.04	585.16	
6	100%			0	660.2	

Alkaline Solution = 336.9 kg/m^3

Mixing and casting of concrete

- Initially fly ash and GGBFS are mixed along with the river sand, Pond ash and aggregates for 2 to 4 min in dry state.
- The alkaline solution is added to the dry mix and mixing is continued for 5 min.
- Based on the percentage of pond ash replaced, the super plasticizer is added to improve the workability of geopolymer concrete.
- This fresh concrete was cast into respective mould for testing. Compaction was done by vibrating it on the vibrating table.
- Curing of the Geopolymer concrete test specimen is done in ambient temperature varying from 24^{o}c to 27^{o}c.

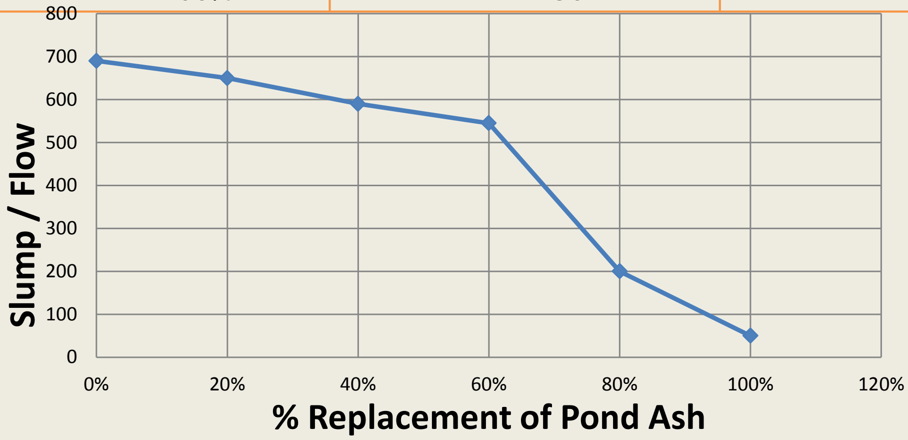
TESTS ON GEO-POLYMER CONCRETE

- Compression test
- Flexural strength
- Split tensile strength
- Water permeability test

RESULTS AND DISCUSSIONS

- **Fresh Property** - The fresh property of geo-polymer concrete is measured in terms of its workability standard slump cone test was done to measure the slump/flow of the concrete.

Sl no	Pond ash content	Slump/Flow values	T_{500}
1)	0%	690	2.98 se
2)	20%	650	3.42 sec
3)	40%	590	49 sec
4)	60%	545	1min 2 sec
5)	80%	200	-
6)	100%	50	-



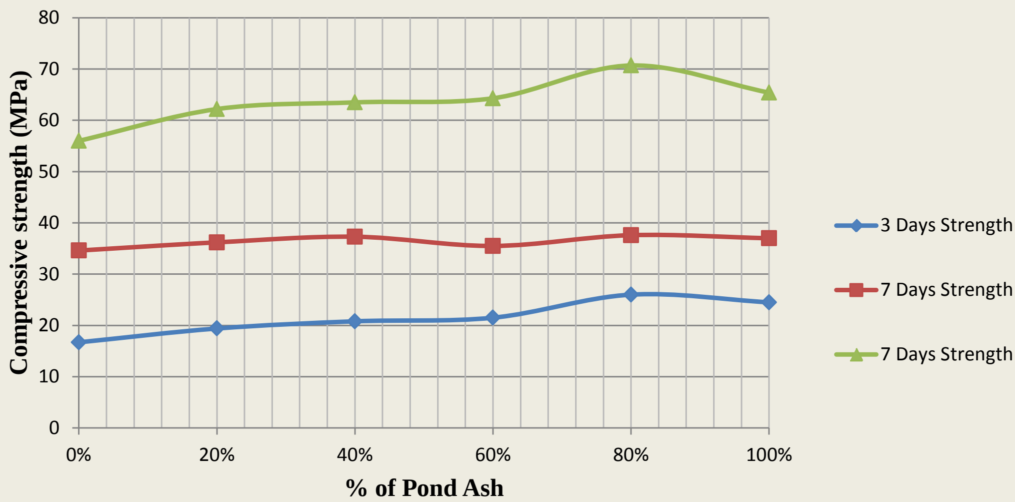
Sl No	Pond Ash Content	Slump without SP	Slump after 0.25% to 0.5% SP
1)	80%	200	250
2)	100%	50	185

Slump in 100% pond ash replacement without SP

Slump in 100% pond ash replacement with SP

Compressive Strength

Sl. No	Pond ash content	Compressive Strength (MPa)		
		3 days	7 days	28 days
1	0%	16.7	34.6	56.0
2	20%	19.4	36.2	62.2
3	40%	20.8	37.3	63.5
4	60%	21.5	35.5	64.3
5	80%	26.0	37.6	70.7
6	100%	24.5	37.0	65.4

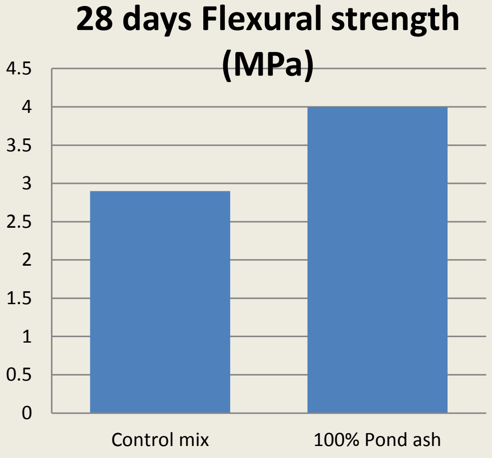


Compressive strength with and without super plasticiser

Sl no	Pond Ash Content	3 days Compressive strength (Mpa)	7 days Compressive strength (Mpa)	28 days Compressive strength (Mpa)
1)	80%	26.0	37.6	70.7
2)	100%	24.5	37.0	65.4
3)	80 % (SP)	22.3	37.5	63.6
4)	100 % (SP)	21.7	36.3	61.6

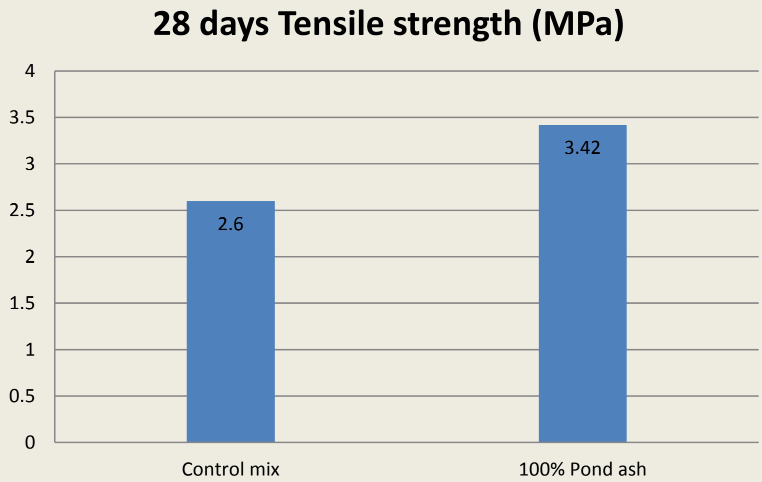
Flexural strength

Specimen	28 days Flexural strength (MPa)
Control mix	3.1
100% Pond ash	4.0



Split tensile strength

Specimen	28 days Tensile strength(MPa)
Control mix	2.6
100% Pond ash	3.4



Water Permeability

Specimen	Maximum water depth in mm
Control mix	20
100% Pond ash	12

TECHNO ECONOMICS

Cost analysis of Control Mix:

Material	Kg/m3	Unit cost (Rs/Kg)	Total Cost
Fly ash	330.1	2.5	825.25
GGBFS	82.525	2.5	206.31
Fine Aggregate (100%)	660.2	4.5	2970.9
Coarse Aggregate	990.3	1	990.3
Alkaline Solution (NaOH + Na_2SiO_3)	268.12	15	4021.80
water	165	1	165
			9,180/-

Cost analysis 100% Pond ash Mix:

Material	Kg/m3	Unit cost (Rs/Kg)	Total Cost
Fly ash	330.1	2.5	825.25
GGBFS	82.525	2.5	206.31
Pond ash (100%)	660.2	0.5	330.2
Coarse Aggregate	990.3	1	990.3
Alkaline Solution (NaOH + Na_2SiO_3)	268.12	15	4021.80
water	165	1	165
			6,538/-

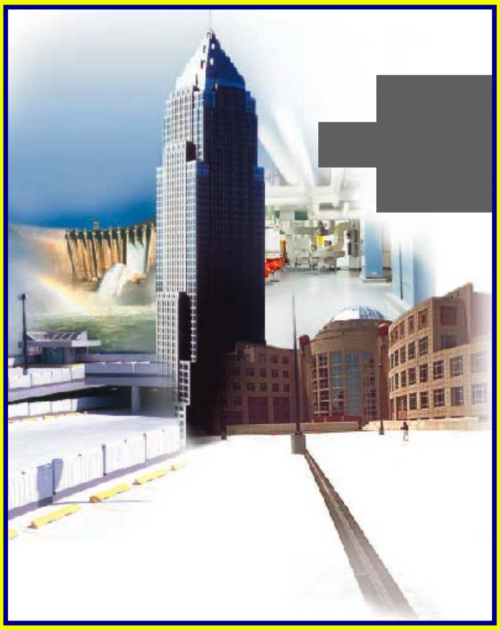
Roller Compacted Concrete

- Roller Compacted Concrete or Rollcrete is a mixture of aggregates, cement/ fly ash/ admixtures and water
- The cement concrete mixture for rollcrete has a consistency nearing zero slump
- Placement of this concrete is done by usual road making equipment

Concluding Remarks

- *Pond ash can be used as Fine aggregate in large quantities in cement concrete.*
- *Geopolymer concrete can be produced using 100% thermal power plant by products namely, Fly ash and pond ash. (Slightly expensive production costs at this point of time)*
- *Engineer's of the future have to shoulder the additional responsibility of conserving the increasingly depleting natural resources by adopting ECO-FRIENDLY technologies.*

Thank you
for your attention



Acknowledgement:
Sincere thanks to Dr. R.N.Pranesh and Dr. M.R. Kalgal for sharing some of their original work.

Do You Want to Make Quality Aggregates & M.Sand?

PROMAN

Crushing Solutions by Professionals

SOTECMA

Técnicas para la manipulación de sólidos

25 AÑOS

REMco

ROCK ENGINEERED MACHINERY CO. INC.

LIPPMANN

Fine Door

Crushing Solutions by Professionals

- Jaw Crushers, Cone Crushers & Vertical Shaft Impact Crushers
- Screens & Feeders
- Fixed, Skid and Mobile Crushing & Screening Plants for Aggregate, Sand & Minerals Projects

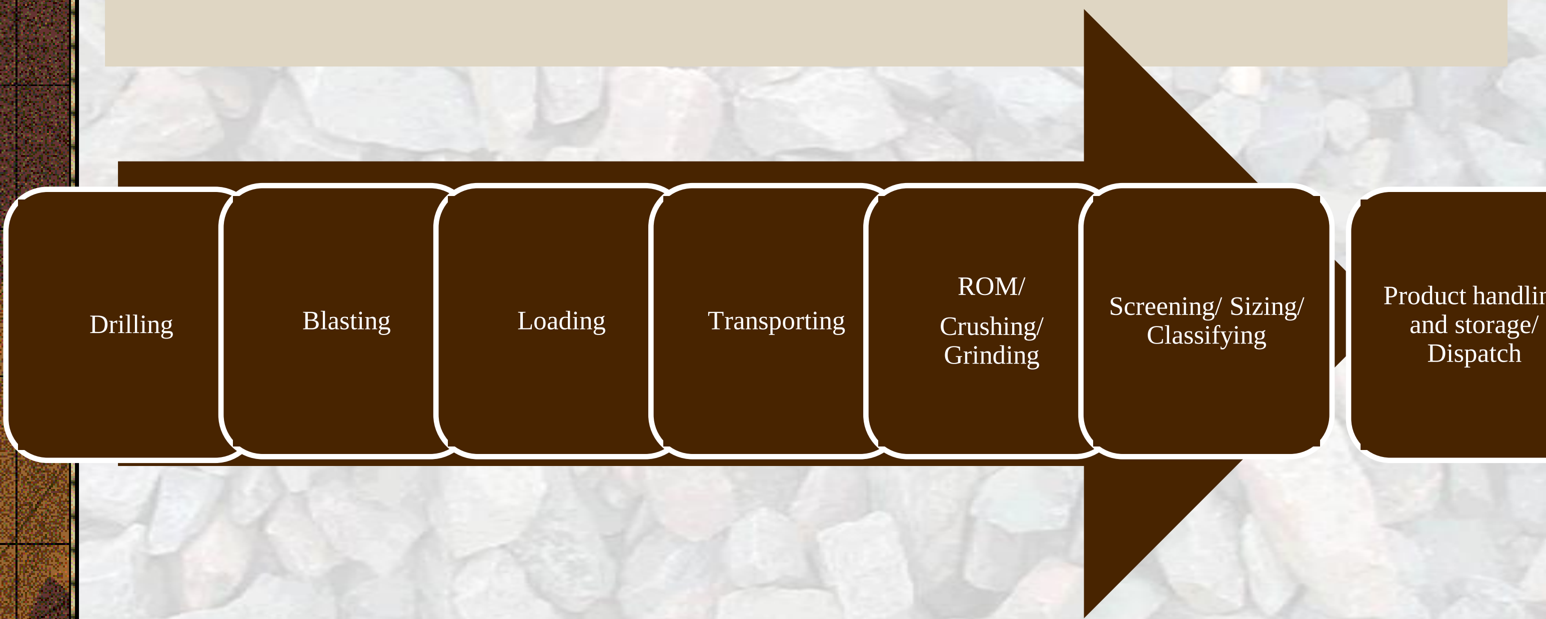
ORTNER

SAND WASHING EQUIPMENT

REMCO.

VERTICAL SHAFT IMPACT CRUSHERS

How to manufacture Quality Aggregate & Sand



Crushing & Screening plant is designed based on the below requirement details

Type of material – Granite/Basalt/Dolomite etc., or Any sound stone used for construction materials

Feed size – 650mm/ 500mm/ 200mm/ 40mm & below etc.,

Material characteristic – Moisture content, B.D, Hardness, strength etc.,

Type of aggregate/sizes, sand, quality & its specifications –IS-383, Zone-2, Zone-3

Capacity in TPH/TPD

Crushers are classified according to the stages based on the feed size, material, reduction ratio, product sizes, capacity and quality.

Primary
Secondary
Tertiary
Quaternary

As stone passes through a crusher, the reduction in size may be expressed as *reduction ratio.*

The reduction ratio is the ratio of crusher feed size to product size.

Based on the reduction ratio (feed size to product size) and application, crushing plants are classified into

- Two stages- Jaw (Primary) + Cone (Secondary) crushers
- Three stages- Jaw + Cone + VSI (Tertiary) crushers
- Four stages – Jaw + Cone + VSI + VSG (Quaternary)

Fines classifier – Dry -PROsizer or Wet –Ortner, PROMAN WSG

What Quality Aggregates

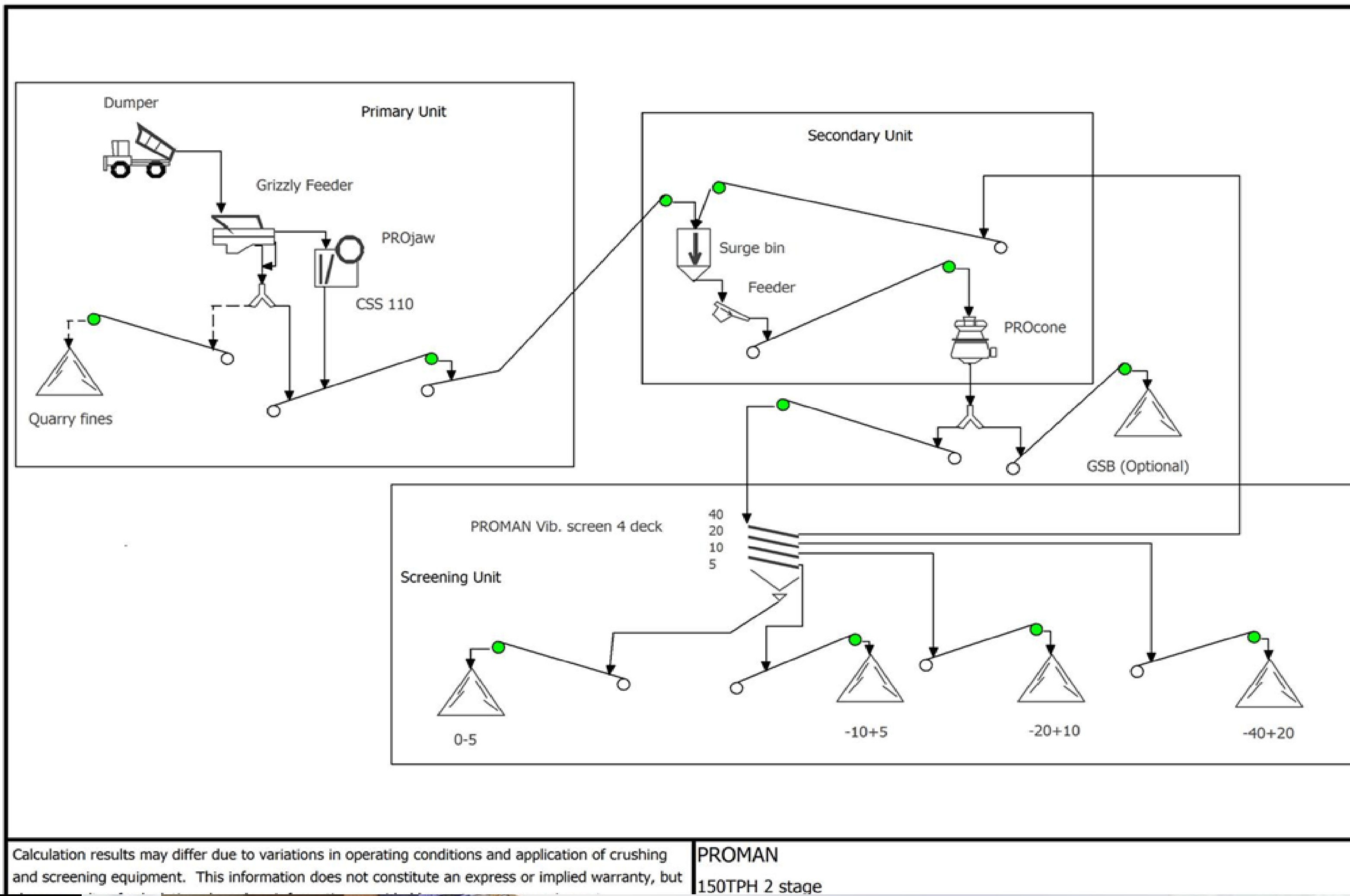
Hard, Strong, Strength

Cubical

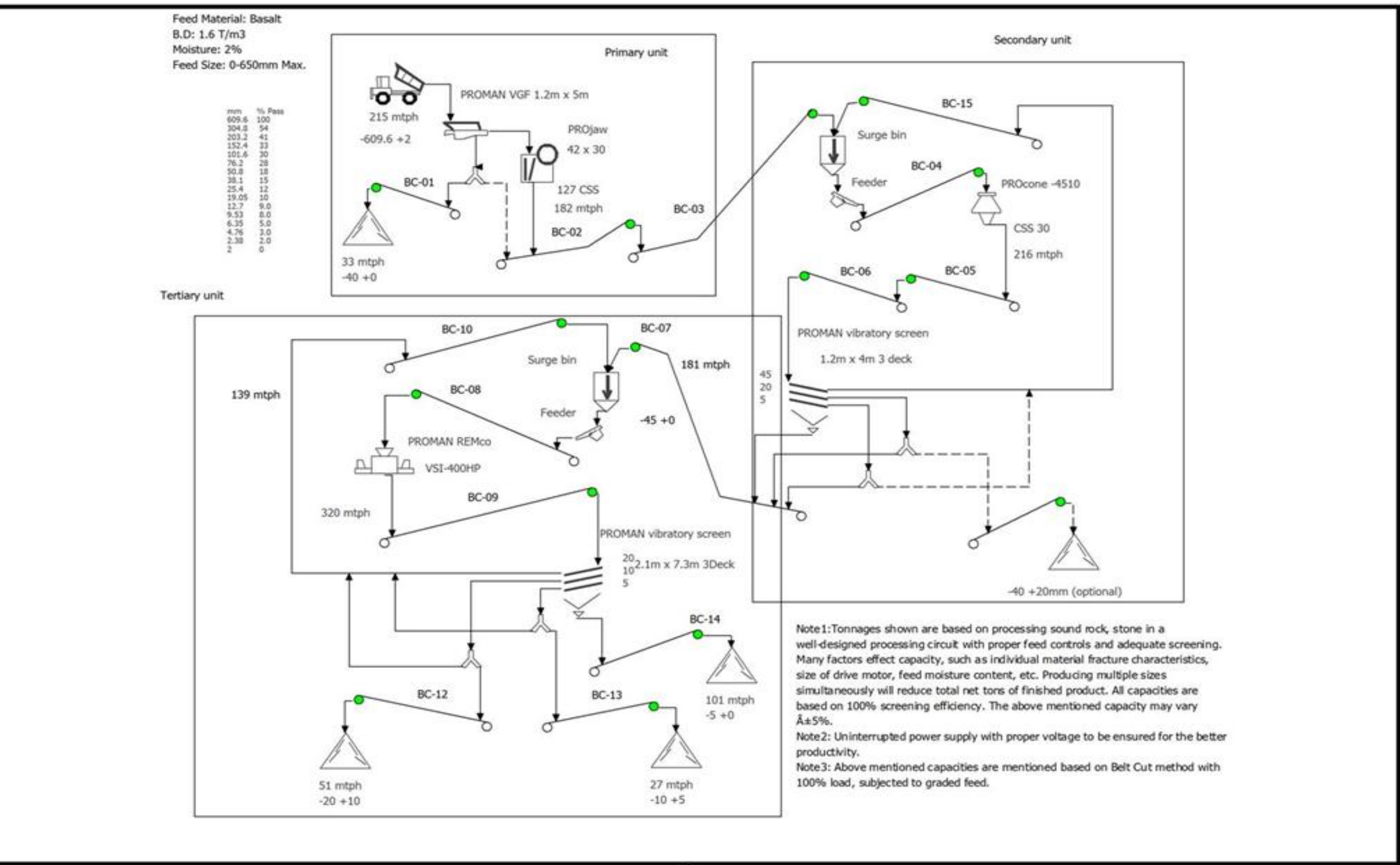
Well Graded

Flakiness & Elongation within the limit

Two Stage Plant



Three Stage Plant



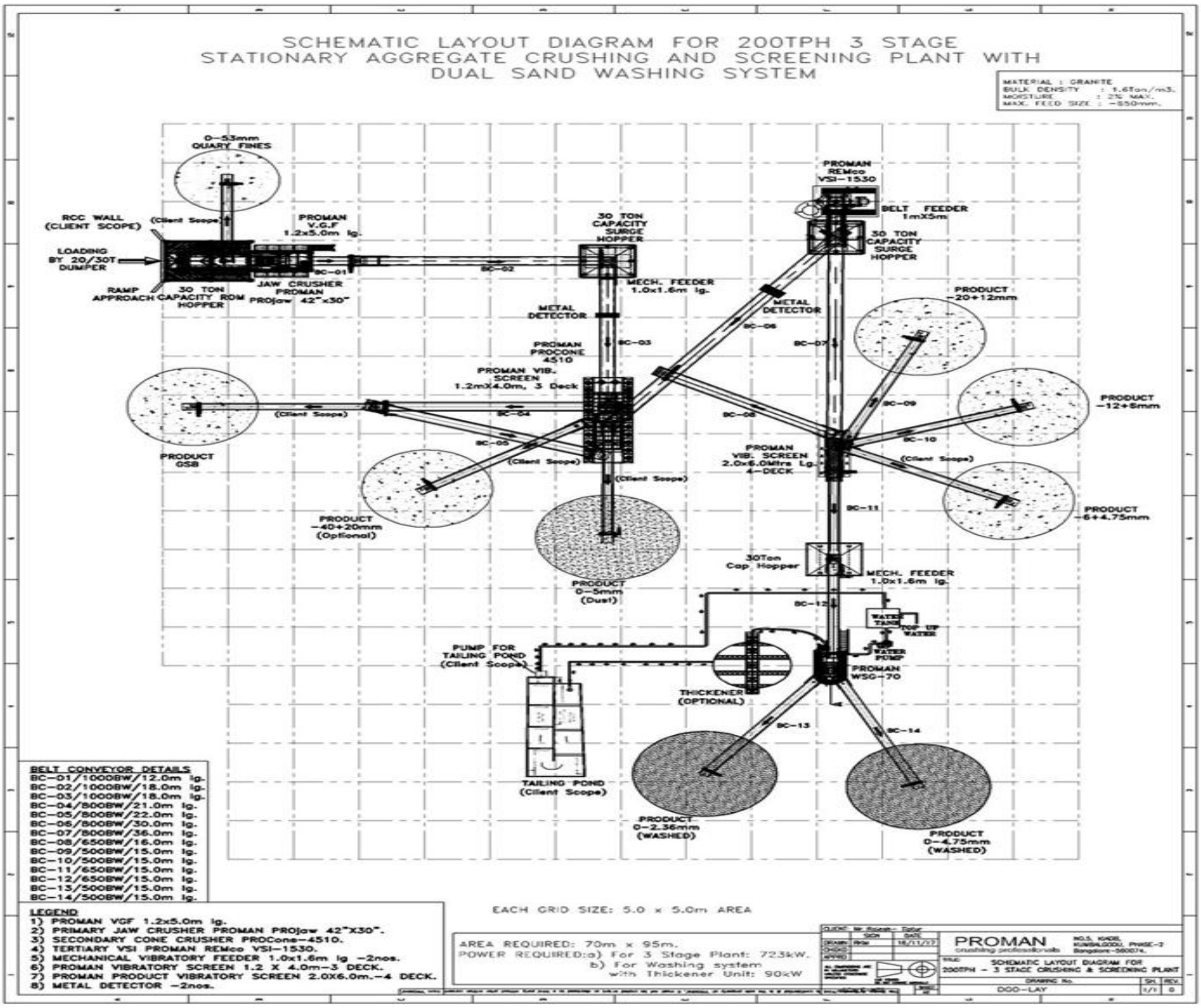
alculation results may differ due to variations in operating conditions and application of crushing and creening equipment. This information does not constitute an express or implied warranty, but shows

PROMAN
200TPH 3 stage -4230,4510, 400









M.Sand

- Ever since man began to build, he has sought quality sand.
- Sand that has round/cubical particles,
- Sand that has a full range of well graded sizes and that finishes smoothly,
- Sand that gives strength and beauty in what man builds.

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Why Need M.Sand

- From the ancient times to the present, good natural sand deposits have been exploited and depleted.
- Now we must crush rock to produce sand for our modern structures.
- No Crushing job is more difficult than producing man made Sand.

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Traditional Method

The demand for economical and efficient sand producing equipment has grown as a natural sand deposits diminish

Different machines have been used to produce and before the development of VSI Crusher

- CONE CRUSHER
- ROD MILLS
- IMPACT CRUSHERS
- ROLL CRUSHERS.

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Rodmill

The Rodmill is capable of producing sand but

- High power cost
- High wear cost
- Produces excess of super fines
- High capital cost

Horizontal Impact Crusher

- High wear cost
- High power cost
- High superfines (<150 microns or 100mesh)
- Also the crushed particles are of angular shape.

Roll Crusher

- Roll Crushers on the other hand have
- Difficulty in producing a sufficient quantity of fines in the NO. 30(600microns), 50(300microns) and 100(150microns)
- Roll shell wear problems.
- Feed restrictions
- High recirculation load

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Cone Crusher

- Very High capital cost
- Flaky material
- Controlling the final gradation is very difficult

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Remember… Making Manufactured Sand Is Harder Than Crushing Rock. Why?

- Sand must be consistent to meet specifications.
- Making sand is the finest crushing requirement in an aggregate production plant.
- Making sand requires more energy per ton to produce, typically 4.5 to 6.5 hp per ton per hour depending on rock hardness.

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Types of Sand

- Manufactured sand for concrete.
- Plastering Sand
- Mortar

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Aggregates & Sand Requires…

- That it complies with the **ASTM C-33** specification and IS 383 Zone-2
- Other types of concrete sand such as masonry and plaster sand are finer grading of the IS 1542 and IS 383 Zone-3
- The **ASTM C-33** sand specification is recognized around the world as the preferred sand grading.

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FINE AGGREGATES IS-383

IS Seive Designation	Percentage passing Over			
	Grading Zone I	Grading Zone II	Grading Zone III	ASTM C-33
10mm	100	100	100	100
4.75 mm (4 mesh)	**90-100**	**90-100**	**90-100**	**95-100**
2.36 mm (8 mesh)	**60-95**	**75-100**	**85-100**	**80-100**
1.18 mm (16 mesh)	**30-70**	**55-90**	**75-100**	**50-85**
600 micron (30 mesh)	**15-34**	**35-59**	**60-70**	**25-60**
300 Microns (50 Mesh)	**5-20**	**8-30**	**12-40**	**10-30**
150 Microns (100 Mesh)	**0-10**	**0-10**	**0-10**	**2-10**
74 Microns (200 Mesh)	**-**	**-**	**-**	**0-5**

Note: For crushed sand sands & crushed gravel sands, the permissible limit on 150 microns IS sieve is increased to 15%. This does not affect the 5% allowance permitted table

PROMAN

IS 1542

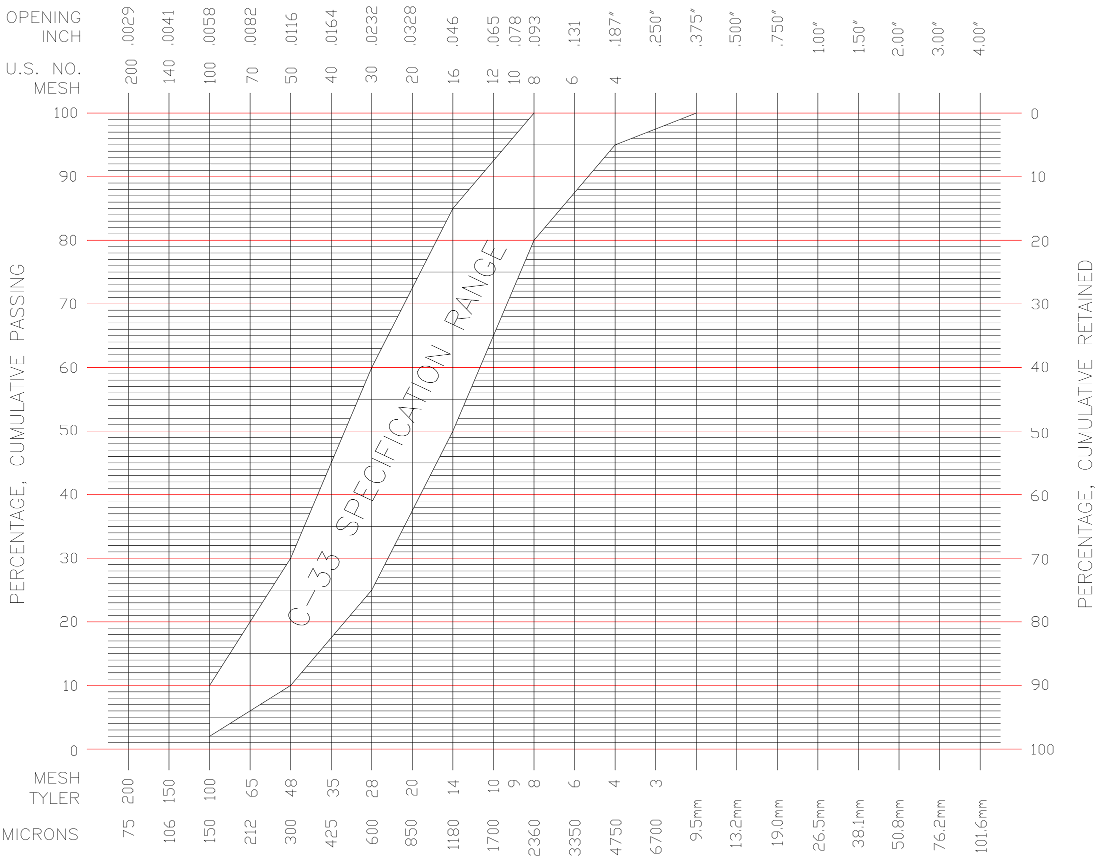
Grading of Sand for Internal Wall or External Wall or Ceiling Plaster	
IS Seive Designation (See IS 460 : 1985)	**Percentage passing Over**
10mm	100
4.75 mm (4 mesh)	95-100
2.36 mm (8 mesh)	95-100
1.18 mm (16 mesh)	90-100
600 micron (30 mesh)	80-100
300 Microns (50 Mesh)	20-65
150 Microns (100 Mesh)	0-15
74 Microns (200 Mesh)	-

Note: For crushed sand sands & crushed gravel sands, the permissible limit on 150 microns IS sieve is increased to 20%. This does not affect the 5% allowance permitted table

What Characteristics Make a Good Manufactured (Crushed Rock) Sand?

- It must be in specification.

PROMAN



REMco ROCK ENGINEERED MACHINERY CO. INC.

SIEVE SIZE	C-33 SPEC.
3/8" (9.5mm)	100
1/4" (6.7mm)	
4M (4.75mm)	95-100
6M (3.55mm)	
8M (2.36mm)	80-100
16M (1.18mm)	50-85
30M (.60mm)	25-60
50M (.30MM)	10-30
100M (.15mm)	2-10
200M (.075mm)	0-5

Graphic Illustration of Grading Curve

PROMAN

What Characteristics Make a Good Manufactured (Crushed Rock) Sand?

- It **must** be in specification.
- It **must** have the required F.M. in order to have good workability and finishing properties in the concrete mix.
- What is F.M.?

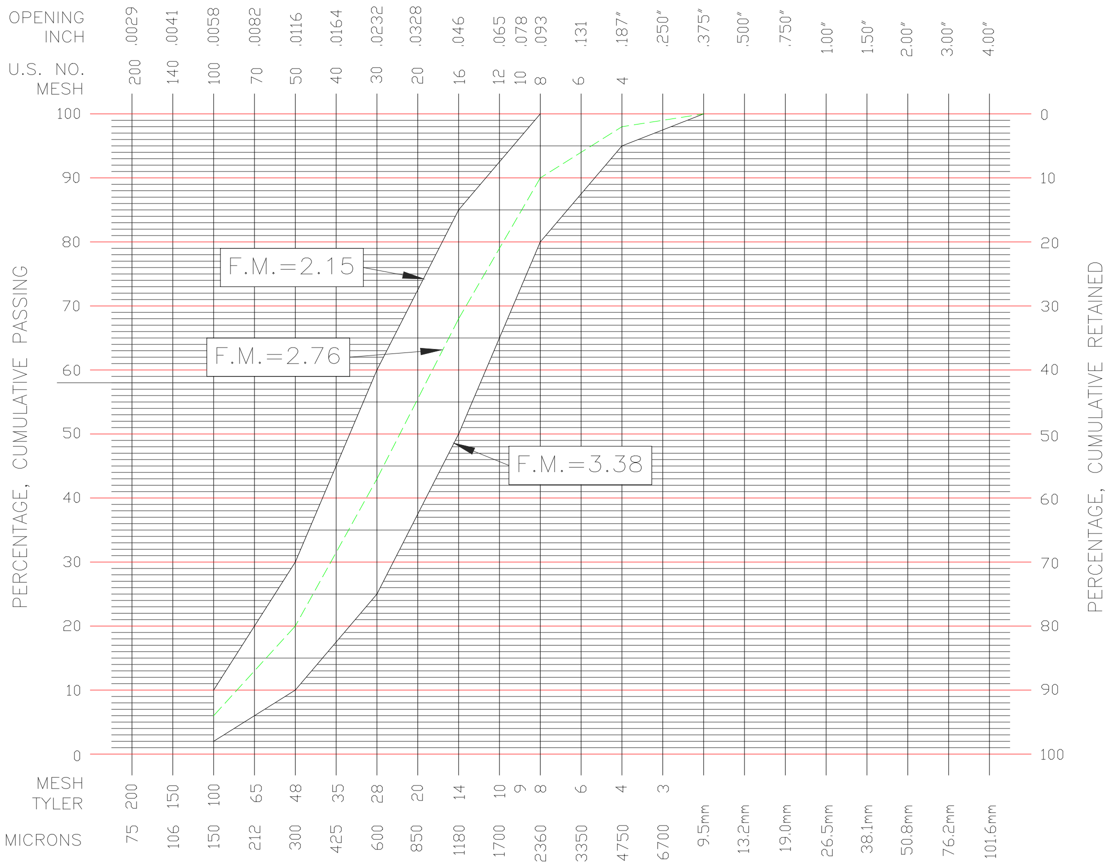
PROMAN

Fineness Modulus (F.M.)

The fineness modulus was developed to indicate the properties of sand in a numerical value indicating the relative fineness or coarseness of a sand sample.

The accumulated percentages retained on Nos. 4,8,16,30,50 and 100 screen sieves are added up and the total divided by 100 giving the F.M. number.

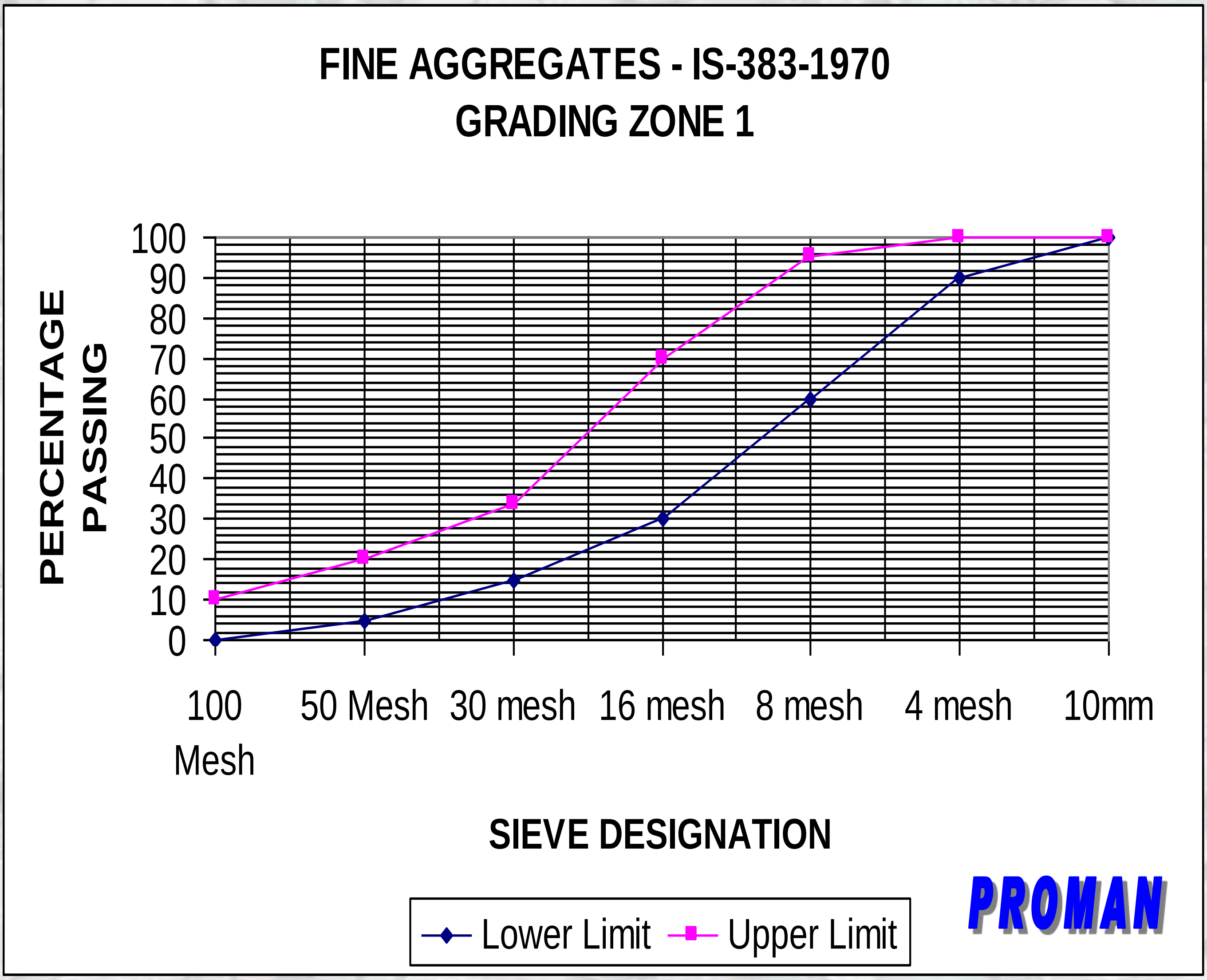
PROMAN



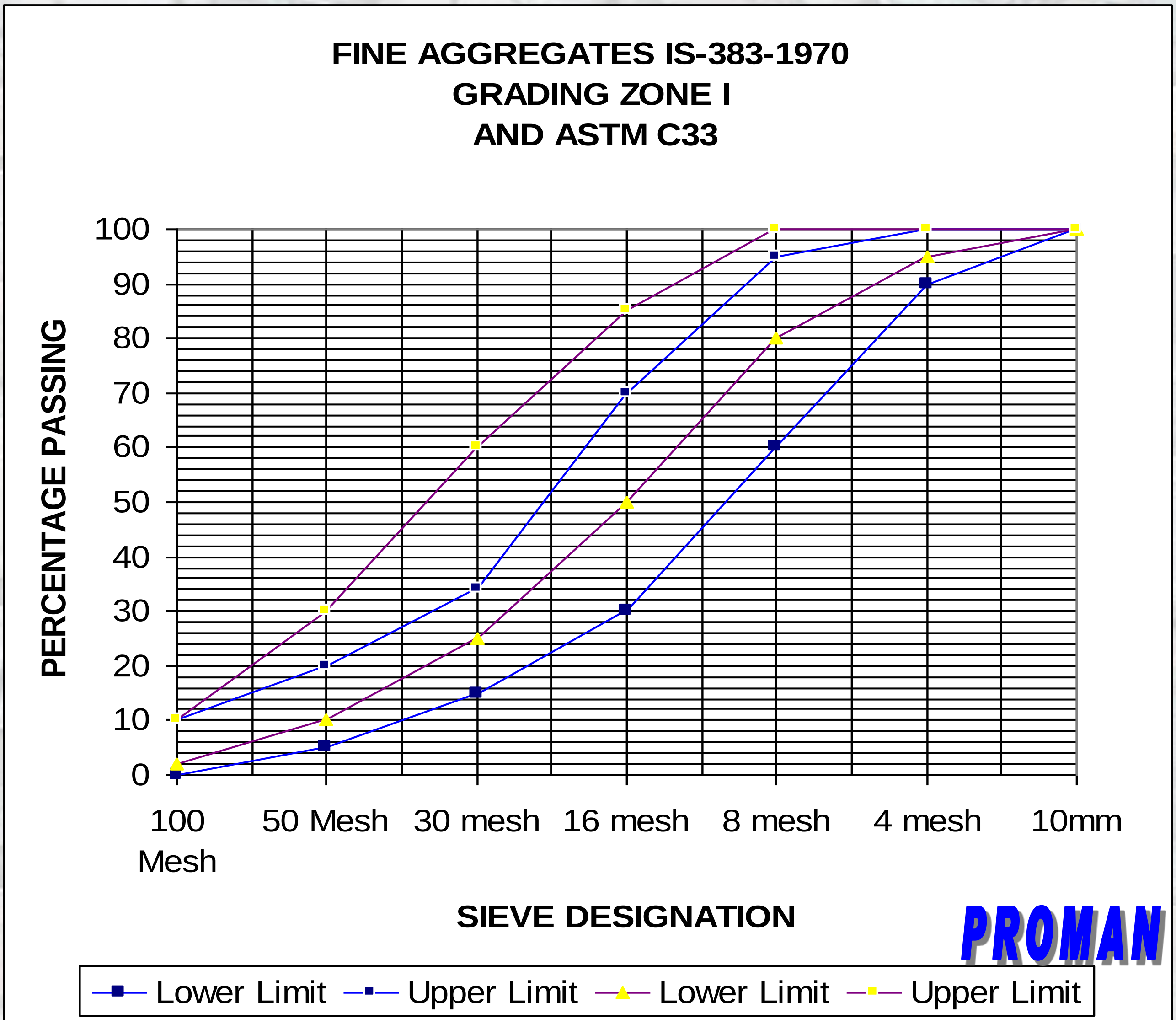
SIEVE SIZE	C-33 SPEC.
3/8" (9.5mm)	100
1/4" (6.7mm)	
4M (4.75mm)	95-100
6M (3.55mm)	
8M (2.36mm)	80-100
16M (1.18mm)	50-85
30M (.60mm)	25-60
50M (.30MM)	10-30
100M (.15mm)	2-10
200M (.075mm)	0-5

Graphic Illustration off Fineness Modulus

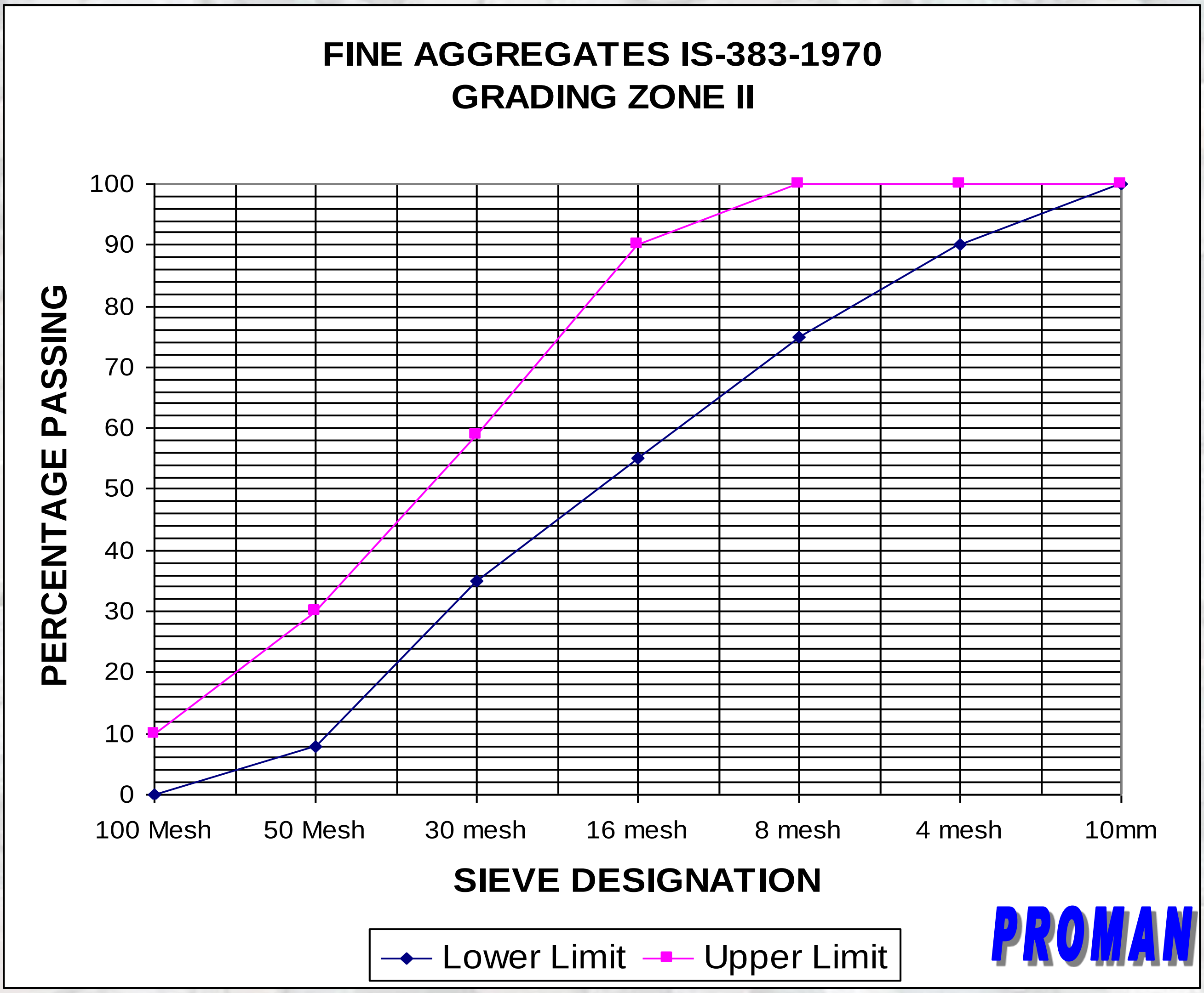
PROMAN

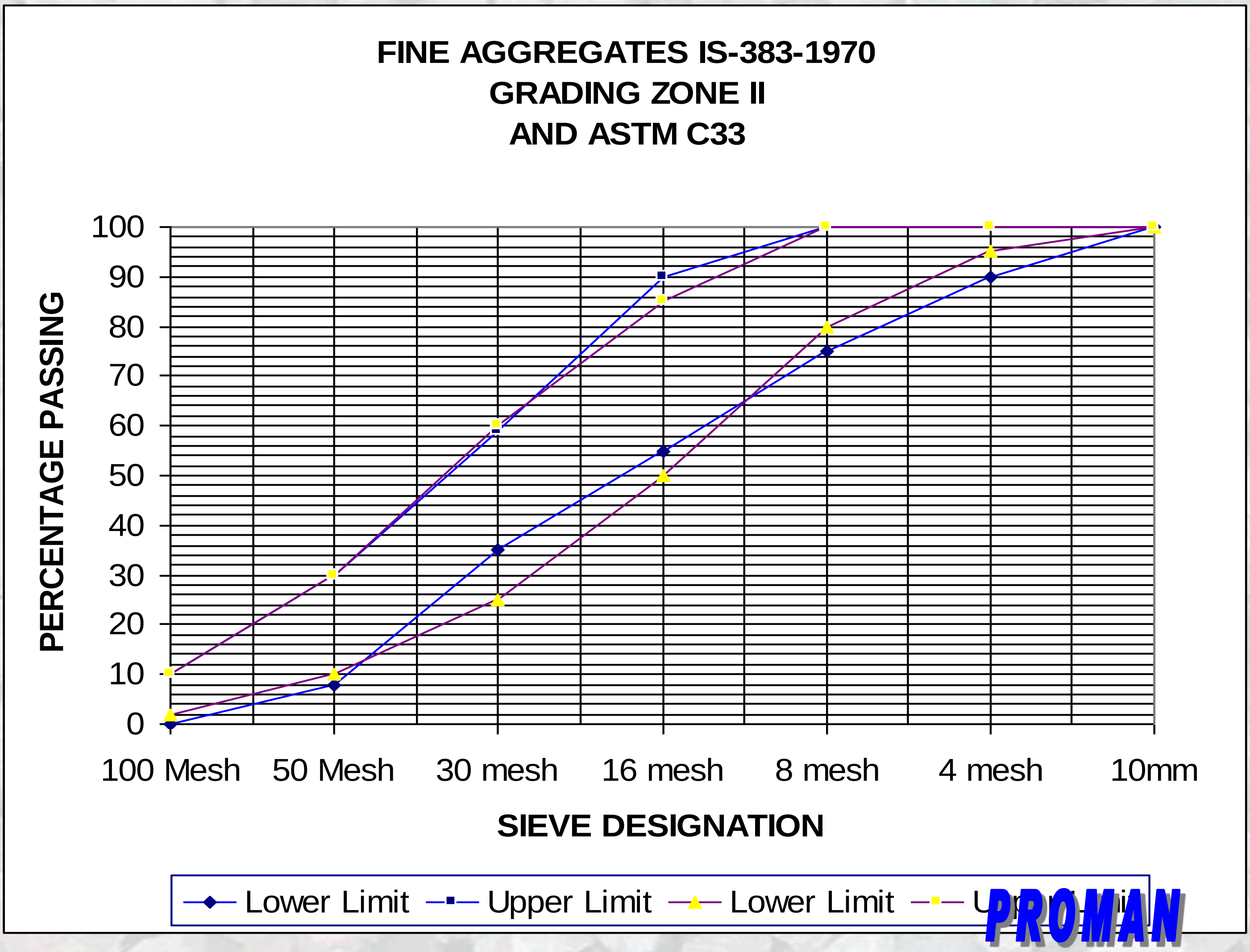


FINE AGGREGATES - IS-383-1970
GRADING ZONE 1
PERCENTAGE PASSING
100
90
80
70
60
50
40
30
20
10
0
100 Mesh
50 Mesh
30 mesh
16 mesh
8 mesh
4 mesh
10mm
SIEVE DESIGNATION
Lower Limit
Upper Limit
PROMAN



FINE AGGREGATES IS-383-1970
GRADING ZONE I
AND ASTM C33
PERCENTAGE PASSING
100
90
80
70
60
50
40
30
20
10
0
100 Mesh
50 Mesh
30 mesh
16 mesh
8 mesh
4 mesh
10mm
SIEVE DESIGNATION
Lower Limit
Upper Limit
Lower Limit
Upper Limit
PROMAN


FINE AGGREGATES IS-383-1970
GRADING ZONE II
PERCENTAGE PASSING
100
90
80
70
60
50
40
30
20
10
0
100 Mesh
50 Mesh
30 mesh
16 mesh
8 mesh
4 mesh
10mm
SIEVE DESIGNATION
Lower Limit
Upper Limit
PROMAN

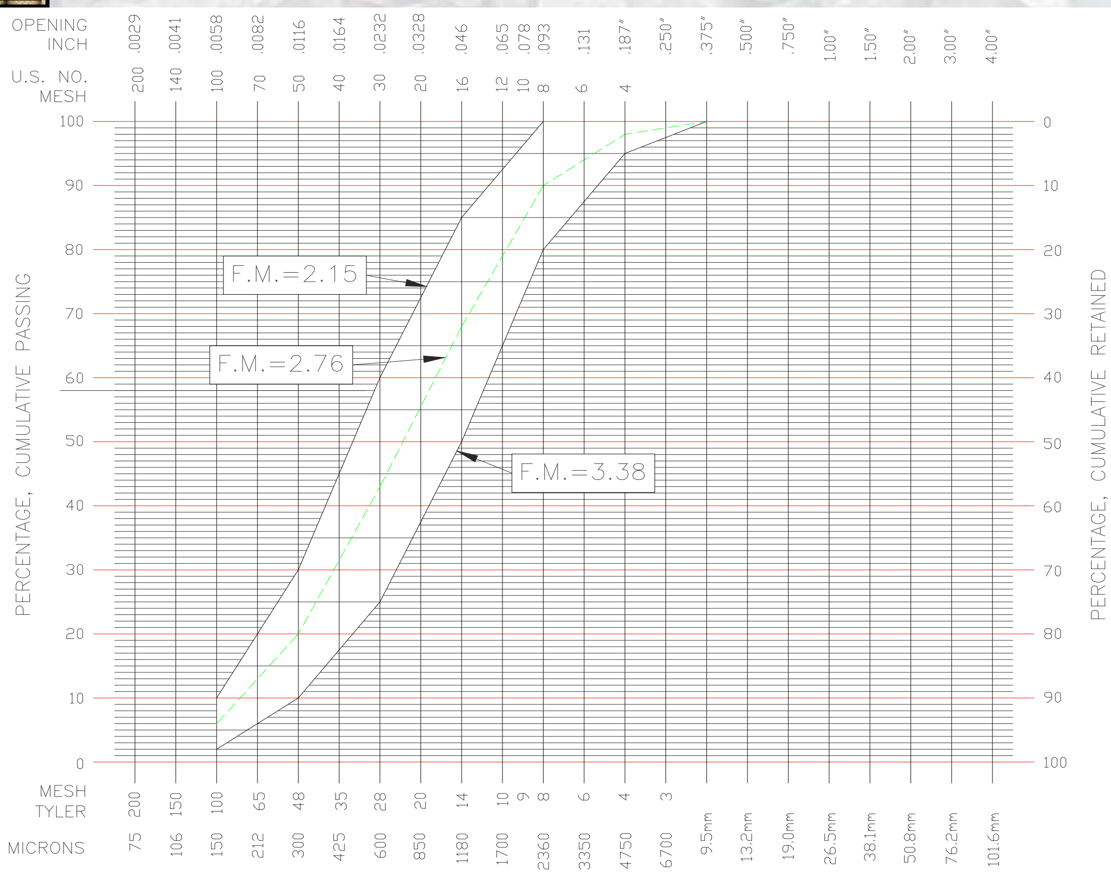

FINE AGGREGATES IS-383-1970
GRADING ZONE II
AND ASTM C33
PERCENTAGE PASSING
100
90
80
70
60
50
40
30
20
10
0
100 Mesh
50 Mesh
30 mesh
16 mesh
8 mesh
4 mesh
10mm
SIEVE DESIGNATION
Lower Limit
Upper Limit
Lower Limit
PROMAN

The Ideal Manufactured Sand Grading Yields an F.M. Number Of 2.76.

The ASTM specification C-33 has an F.M. range of a low of 2.16 or a high of 3.38 with the optimum being 2.76.

Typically an F.M. number of 3.0 or less is generally commercially acceptable.

PROMAN



REMco ROCK ENGINEERED MACHINERY CO. INC.

SIEVE SIZE	C-33 SPEC.
3/8" (9.5mm)	100
1/4" (6.7mm)	
4M (4.75mm)	95-100
6M (3.55mm)	
8M (2.36mm)	80-100
16M (1.18mm)	50-85
30M (.60mm)	25-60
50M (.30MM)	10-30
100M (.15mm)	2-10
200M (.075mm)	0-5

Graphic Illustration off Fineness Modulus

PROMAN

What Characteristics Make a Good Manufactured (Crushed Rock) Sand?

- It **must** be in specification.
- It **must** have the required F.M. number in order to have good workability and finishing properties in the concrete mix.
- What is F.M.?
- It must have cubical particles for all sieve sizes.

PROMAN

Importance of sand quality

Fine Aggregates:

The fine aggregates or sand plays an important role in the design of concrete especially where pump mixes are used.

The specific sand being used can sometimes spell the difference between success and failure.

In many instances when trouble develops deficiencies in the fine aggregate or Sand are found to be the cause.

PROMAN

Magnified Photo Granite

Cone Crusher Sand 10m x 30m (1.7mm x 0.6mm)fraction

Magnified Photo Granite

REMco VSI Sand 10m x 30m Fraction

What Characteristics Make a Good Manufactured (Crushed Rock) Sand?

- It **must** be in specification.
- It **must** have the required F.M. in order to have good workability and finishing properties in the concrete mix.
- What is F.M.?
- It must have cubical particles for all sieve sizes.
- It must be removed excess fines

PROMAN

What Materials Can Be Crushed To Make Manufactured Sand?

- Limestone
- Granite
- Basalt
- Gravel
- Andesite
- Sandstone
- Silica
- Quartzite
- Slag

Any sound stone used for construction materials

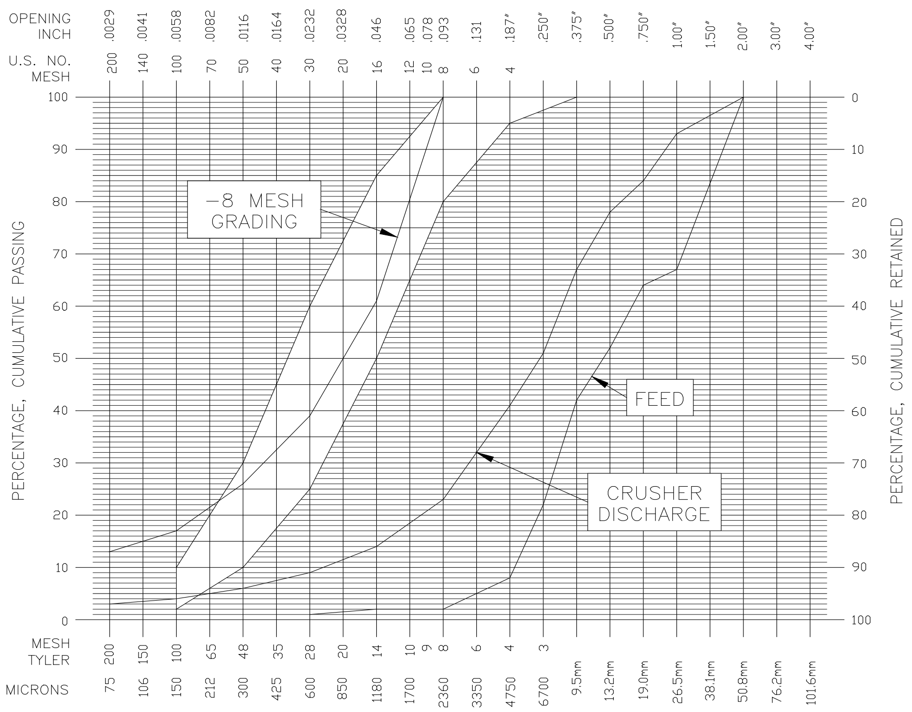
PROMAN

REMco
263 S. Vasco Road
Livermore CA 94550
(925) 447-0805
ROCK ENGINEERED MACHINERY CO. INC.

TEST NUMBER: RBA-00055
CUSTOMER: SIERRA READY MIX
LOCATION: STATELINE, NEVADA
DATE: 01/04/01
MACHINE MODEL: 5500 TESTMAX
TESTED BY: REMco

ROTOR SIZE: 23"-4 PORT
CHAMBER LINER: ROCK
MOTOR HP.: 75
AMPS: 80
SPEED: 270 FT/SEC

MATERIAL CHARACTERISTICS: ALLUVIAL DEPOSIT. PREDOMINATELY GRANITE.



PRODUCT REQ'D.: C-33
TYPE OF MATERIAL: PIT RUN MATERIAL
PERCENT MOISTURE: %
TOTAL SAMPLE WEIGHT:

GRADING TEST RESULTS FROM CRUSHER:
SINGLE PASS [X] CLOSED CIRCUIT [ ]

SIEVE SIZE	% PASS FEED	% PASS CRUSHER DISCHARGE	-8 MESH GRADING
2"	100	100	
1 1/2"			
1"	67	93	
3/4"	64	84	
1/2"	52	78	
3/8"	42	67	
1/4"	22	51	
4 M	8	41	
8 M	2	23	100
16 M	2	14	61
30 M	1	9	39
50 M		6	26
100 M		4	17
200 M		3	13
TOTAL			

REMARKS: THIS WAS AN OPEN CIRCUIT TEST. A CLOSED CIRCUIT WILL PRODUCE FINER MATERIAL ALLOWING THE C-33 TO BE MADE ON 6M.

REMco

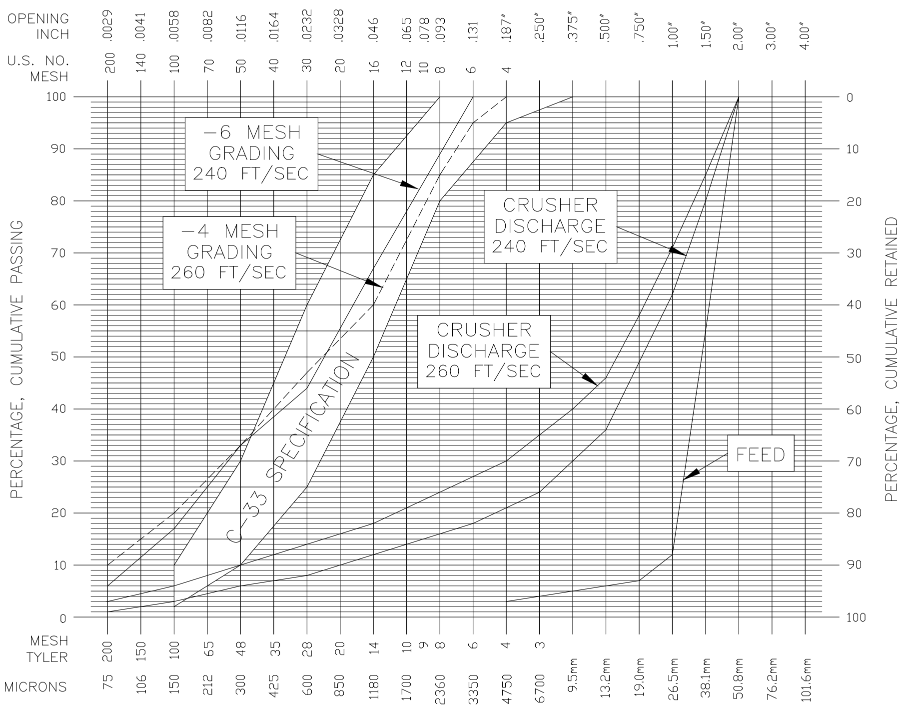
263 S. Vasco Road
Livermore CA 94550
(925) 447-0805

ROCK ENGINEERED MACHINERY CO. INC.

TEST NUMBER: RBA-01003
CUSTOMER: H & K MATERIALS
LOCATION: LOCUST RIDGE, PA
DATE: 05/22/01
MACHINE MODEL: 5500 TESTMAX
TESTED BY: REMco

ROTOR SIZE: 23"-4 PORT
CHAMBER LINER: ROCK
MOTOR HP.: 75
AMPS: FULL
SPEED: 240 FT/SEC
260 FT/SEC

MATERIAL CHARACTERISTICS: SHARP ANGULAR MATERIAL WITH SOME FINES



PRODUCT REQ'D.: SAND
TYPE OF MATERIAL: SANDSTONE
PERCENT MOISTURE: 2%
TOTAL SAMPLE WEIGHT:

GRADING TEST RESULTS FROM CRUSHER:
SINGLE PASS [X] CLOSED CIRCUIT [ ]

SIEVE SIZE	% PASS FEED	% PASS CRUSHER DISCHARGE 240 FT/SEC	-6 MESH GRADING	% PASS CRUSHER DISCHARGE 260 FT/SEC	-4 MESH GRADING
2"	100	100		100	
1 1/2"	55	80		85	
1"	12	62		71	
3/4"	7	49		58	
1/2"	6	36		46	
3/8"	5	30		40	
1/4"	4	24		35	
4 M	3	21		30	100
6 M		18	100	27	90
8 M		16	89	24	80
16 M		12	67	18	60
30 M		8	44	14	47
50 M		6	33	10	33
100 M		3	17	6	20
200 M		1	6	3	10
TOTAL					

REMARKS: THIS MATERIAL RESPONDS WELL TO IMPACT CRUSHING. A REMco CRUSHER OPERATING IN CLOSED CIRCUIT WILL PRODUCE A FINER DISCHARGE GRADING. THE GAP GRADED FEED USED IN THIS TEST HINDERS CRUSHER PERFORMANCE.

REMco

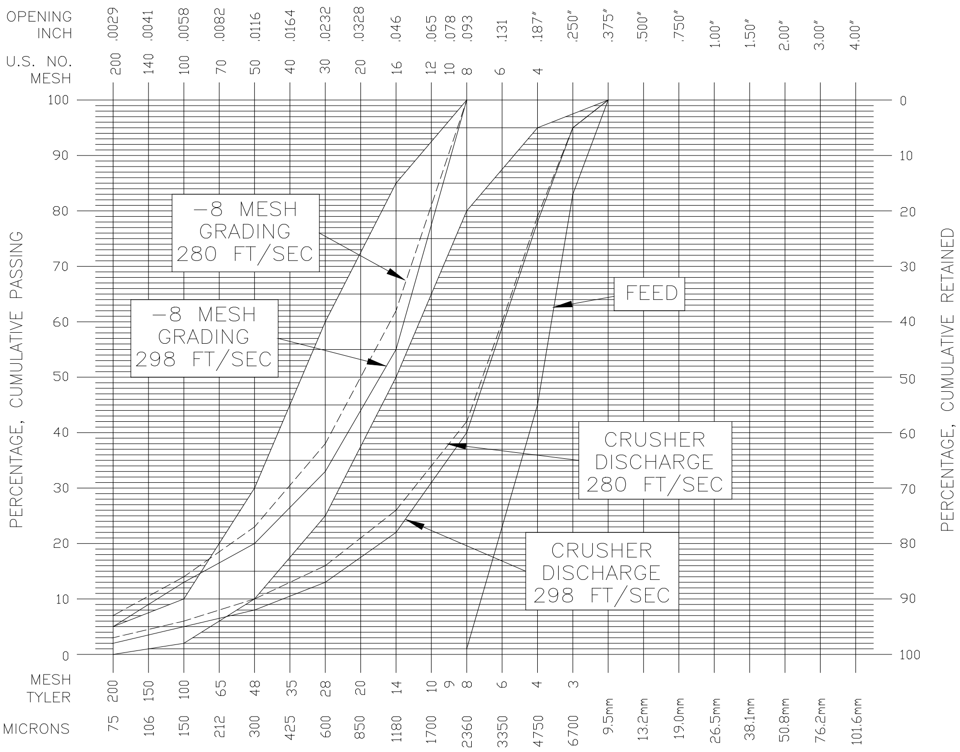
263 S. VASCO ROAD
Livermore CA 94550
(925) 447-0805

ROCK ENGINEERED MACHINERY CO. INC.

TEST NUMBER: RBA-01059 A
CUSTOMER: THE TANNER CO.
LOCATION: YUMA, AZ
DATE: 10/24/01
MACHINE MODEL: 5500 TESTMAX
TESTED BY: REMco

ROTOR SIZE: 23"-4 PORT
CHAMBER LINER: ROCK
MOTOR HP.: 75
AMPS: FULL
SPEED: 280 FT/SEC
298 FT/SEC

MATERIAL CHARACTERISTICS: SMALL PEA SIZE AND CUBICAL GRANITE W/ SOME SHARDS. MULTICOLORED



PRODUCT REQ'D.: C-33 SAND
TYPE OF MATERIAL: GRANITE
PERCENT MOISTURE: <1%
TOTAL SAMPLE WEIGHT: N/A

GRADING TEST RESULTS FROM CRUSHER:
SINGLE PASS [X] CLOSED CIRCUIT [ ]

SIEVE SIZE	CUMULATIVE % PASS FEED	CUMULATIVE % PASS PRODUCT 280 FT/SEC		CUMULATIVE % PASS PRODUCT 298 FT/SEC		C-33 SPEC.
2"						
1 1/2"						
1"						
3/4"						
1/2"						
3/8"	100	100		100		100
1/4"	83	95		95		
4	45	79		78		95–100
6	23	60		60		
8	1	42	100	40	100	80–100
16		26	62	22	55	50–85
30		16	38	13	33	25–60
50		10	23	8	20	10–30
100		6	14	5	13	2–10
200		3	7	2	5	0–5
TOTAL						

REMARKS: TEST CRUSHER PERFORMED WELL WITH THIS MATERIAL, POWER DRAW WAS STEADY AND CONSTANT.

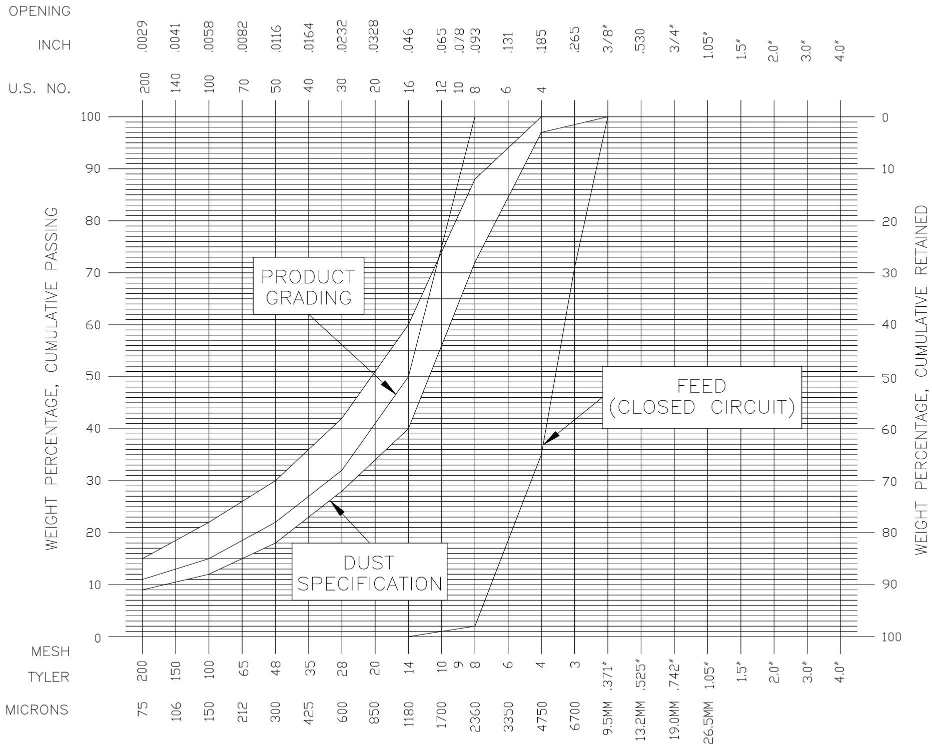
263 S. VASCO ROAD
Livermore CA 94550
(925) 447-0805

ROCK ENGINEERED MACHINERY CO. INC.

TEST NUMBER: RBA-94032
CUSTOMER: MARK WEST QUARRY
LOCATION: SANTA ROSA, CA
DATE: 10/06/94
MACHINE MODEL: 2000 TESTMAX

ROTOR SIZE: 12"
MOTOR HP.: 15
AMPS: 38-40
SPEED: FULL

TESTED BY: REMco
MATERIAL CHARATERISTICS:



PRODUCT REQ'D.: SPECIFICATION CRUSHER DUST
TYPE OF MATERIAL: BASALT, QUARRIED STONE
PERCENT MOISTURE: %
TOTAL SAMPLE WEIGHT: 1500 GR.

GRADING TEST RESULTS FROM CRUSHER:
SINGLE PASS [ ] CLOSED CIRCUIT [X]

SIEVE SIZE	CUMULATIVE % PASS FEED	CUMULATIVE % PASS PRODUCT	REDWOOD HOT PLANT DUST SPECIFICATION	
2"				
1 1/2"				
1"				
3/4"				
1/2"				
3/8"	100		100	100
1/4"	71			
4	35		97	100
8	2	100	72	88
16	1	50	40	60
30		32	28	42
50		22	18	30
100		15	12	22
200		11	9	15
TOTAL				

REMARKS: CRUSHER RAN WELL, DUST WAS CONTROLABLE. ROCK IS FINE GRAINED AND STRONG.

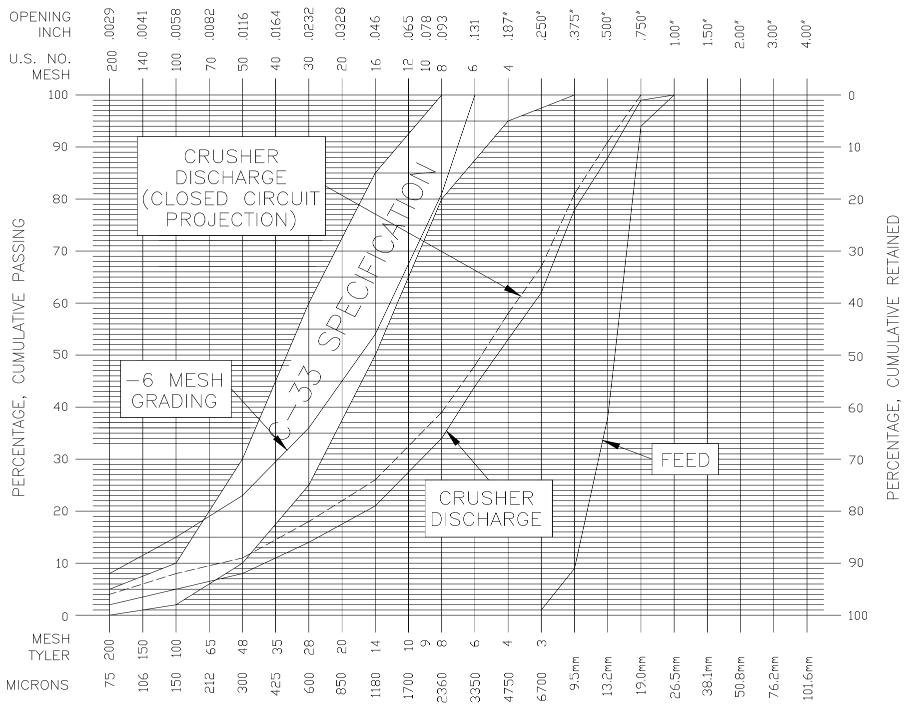
263 S. VASCO ROAD
Livermore CA 94550
(925) 447-0805

ROCK ENGINEERED MACHINERY CO. INC.

TEST NUMBER: RBA-98121
CUSTOMER: HILLSDALE ROCK COMPANY
LOCATION: SAN JUAN BAUTISTA, CA.
DATE: 10/19/98
MACHINE MODEL: 5500 TESTMAX

ROTOR SIZE: 23"-4 PORT
MOTOR HP.: 50
AMPS: FULL
SPEED: 240 FT/SEC

TESTED BY: REMco
MATERIAL CHARACTERISTICS: RIVER GRAVEL-CLEAN, WET, ROUNDED.



PRODUCT REQ'D.: C-33 SAND
TYPE OF MATERIAL: GRAVEL
PERCENT MOISTURE: 3 %
TOTAL SAMPLE WEIGHT:

GRADING TEST RESULTS FROM CRUSHER:
SINGLE PASS [X] CLOSED CIRCUIT [ ]

SIEVE SIZE	% PASS FEED	% PASS CRUSHER DISCHARGE OPEN	% PASS CRUSHER DISCHARGE CLOSED	-6 MESH GRADING	C-33 SPEC.
1 1/2"					
1"	100				
3/4"	94	99	100		
1/2"	38	88	91		
3/8"	9	78	81		100
1/4"	.5	62	67		
4		53	58		95-100
6		44	48	100	
8		34	39	81	80-100
16		21	26	54	50-85
30		14	18	36	25-60
50		8	11	23	10-30
100		5	8	15	2-10
200		2	4	8	0-5
TOTAL					

REMARKS: ROTOR SPEED AND NUMBER OF PORTS WILL HAVE SIGNIFICANT EFFECT ON THIS MATERIAL. SLOWER SPEEDS WILL PRODUCE A PRODUCT WHICH IS MORE COARSE.

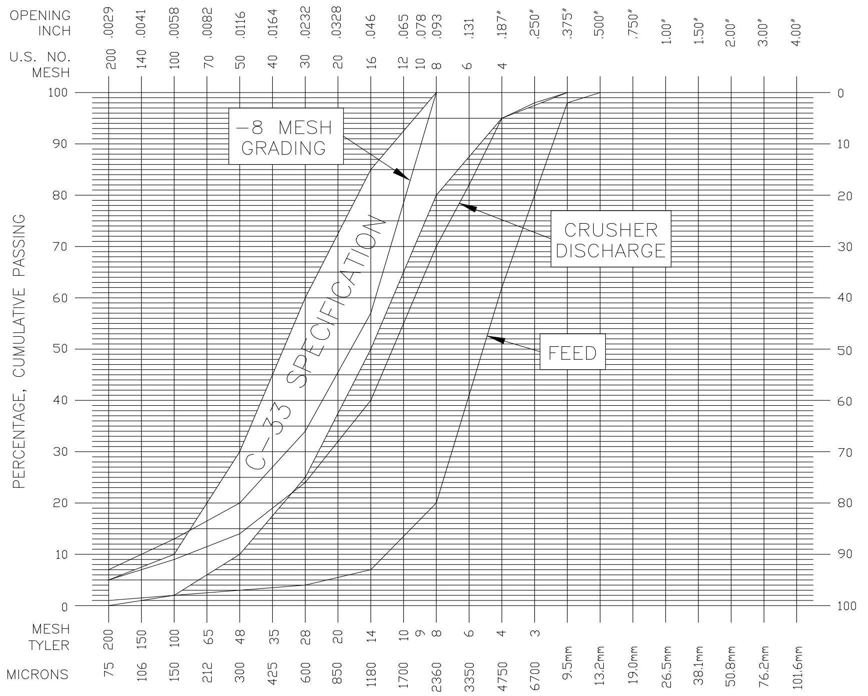
REMco
263 S. VASCO ROAD
Livermore CA 94550
(925) 447-0805
ROCK ENGINEERED MACHINERY CO. INC.

TEST NUMBER: RBA-99035 Test A
CUSTOMER: GRANITE CONSTRUCTION
LOCATION: LAS VEGAS, NV
DATE: 05/24/99
MACHINE MODEL: 5500 TESTMAX

ROTOR SIZE: 23"-4 PORT
MOTOR HP.: 50
AMPS: FULL
SPEED: 280 FT/SEC
ANVIL CHAMBER

TESTED BY: REMco

MATERIAL CHARACTERISTICS: LIMESTONE CHIPS 3/8" X 8 MESH VARIED COLOR WHITE TO DK GRAY.



PRODUCT REQ'D.: SAND
TYPE OF MATERIAL: LIMESTONE DOLOMITE
PERCENT MOISTURE: % N/A
TOTAL SAMPLE WEIGHT: 1 DRUM

GRADING TEST RESULTS FROM CRUSHER:
SINGLE PASS [X] CLOSED CIRCUIT [ ]

SIEVE SIZE	CUMULATIVE % PASS FEED	CUMULATIVE % PASS PRODUCT	C-33 SPEC.	-8 MESH GRADING
1 1/2"				
1"				
3/4"				
1/2"	100			
3/8"	98	100	100	
1/4"	80	98		
4	62	95	95-100	
8	20	70	80-100	100
16	7	40	50-85	57
30	4	24	25-60	34
50	3	14	10-30	20
100	2	9	2-10	13
200	1	5	0-5	7
TOTAL				

REMARKS: THIS TEST WAS DONE WITH AN AUTOGENOUS ROTOR AND AN ANVIL RING. THE ROCK RESPONDS WELL TO IMPACT CRUSHING. A SLIGHTLY FINER DISCHARGE GRADING WILL BE PRODUCED BY A REMco CRUSHER OPERATING IN A CLOSED CIRCUIT.

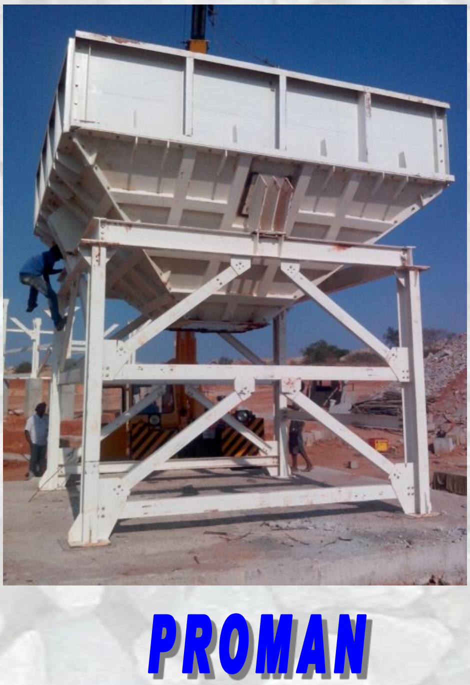
Aggregate & Sand Manufacturing Circuit That Works Right?

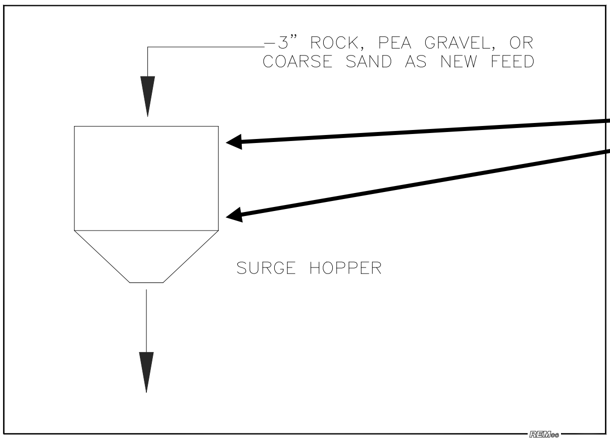
First We See Flow Sheets Of 2 Stage Plant and 3 Stage Plant That Is Needed.

PROMAN

We Make A Flow Sheet Of The Tertiary Unit That Is Needed.

- We start with a surge bin.





Bin to be fitted with high and low level indicators.

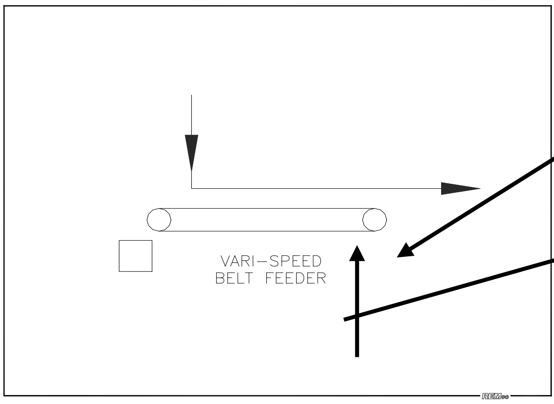
A surge bin is necessary to provide a ready large quantity of new feed to the crusher. The surge bin protects the crushed sand circuit from the production irregularities in other parts of the crushing plant.

The surge bin should be filled with clean well graded material having a maximum of 3" (75mm) or any smaller size of sound stone or gravel.

How Do We Build A Spec Sand Manufacturing Circuit?

- We start with a surge.
- We add a feeder.

PROMAN



Material flow to the feeder must be controlled by an adjustable gate. Feeders should have a 5 degree incline to allow for free water drainage with wet materials.

A feeder is essential because it controls the rate of new feed introduced to the sand circuit. A feeder allows optimum and continuous flow of new feed. Belt feeders are preferred because of their linear capacity.

Electro mechanical vibrating feeders are also acceptable but provide less control at maximum feed rates requiring that they be oversize.

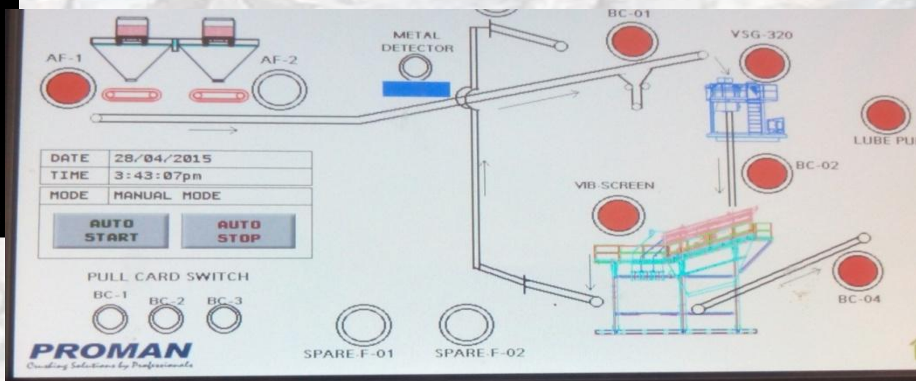
PROMAN

How Do We Build A Spec Sand Manufacturing Circuit?

- We start with a surge.
- We add a feeder.
- We include automation.

PROMAN

Automation protects the crusher and circuit from overload.



The addition of automation will increase sand production 10% to 30%.

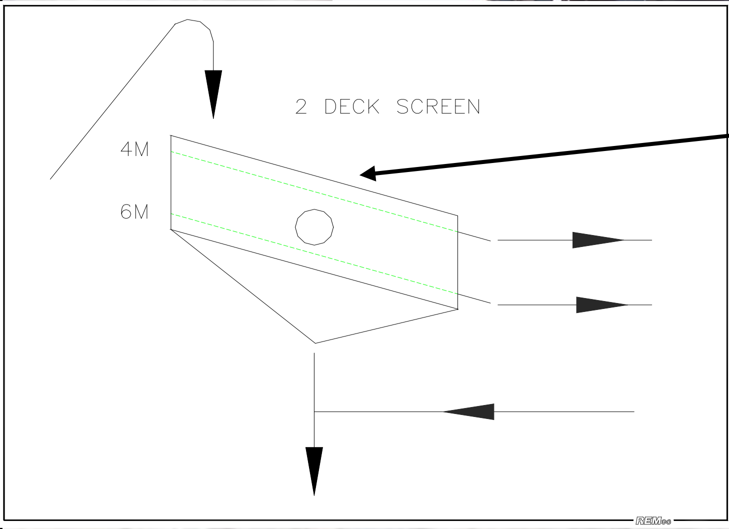
Automation eliminates the “human factor”, lowers operating cost and ensures maximum feed rate to utilize all the connected crushing power.

Automation ensures continuous crusher discharge grading.

PROMAN

How Do We Build A Spec Sand Manufacturing Circuit?

- We start with a surge.
- We add a feeder.
- We include automation.
- We select a proper screen.



The screen should be enclosed for dust control.

A sand circuit screen must be designed for fine screening below 3/16” (4.75mm).

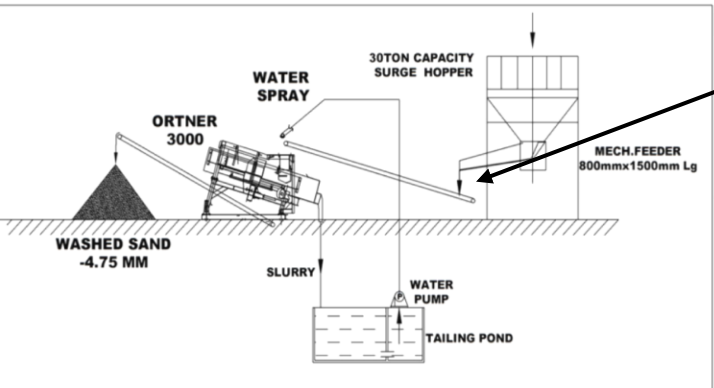
It may be 2, 3 or 4 deck type. It can be horizontal or incline style.

It must be conservatively sized, preferably oversized.

How Do We Build A Spec Sand Manufacturing Circuit?

- We start with a surge.
- We add a feeder.
- We include automation.
- We select a proper screen.
- Add a classifier Dry/Wet.

PROMAN



Pool size adjustment and chemical additives improve ORTNER performance.

The sand washer/dewatering equipment (ORTNER) must be sized for the maximum tonnage of sand produced. It removes the excess Fines minus 100m (.150mm) as waste.

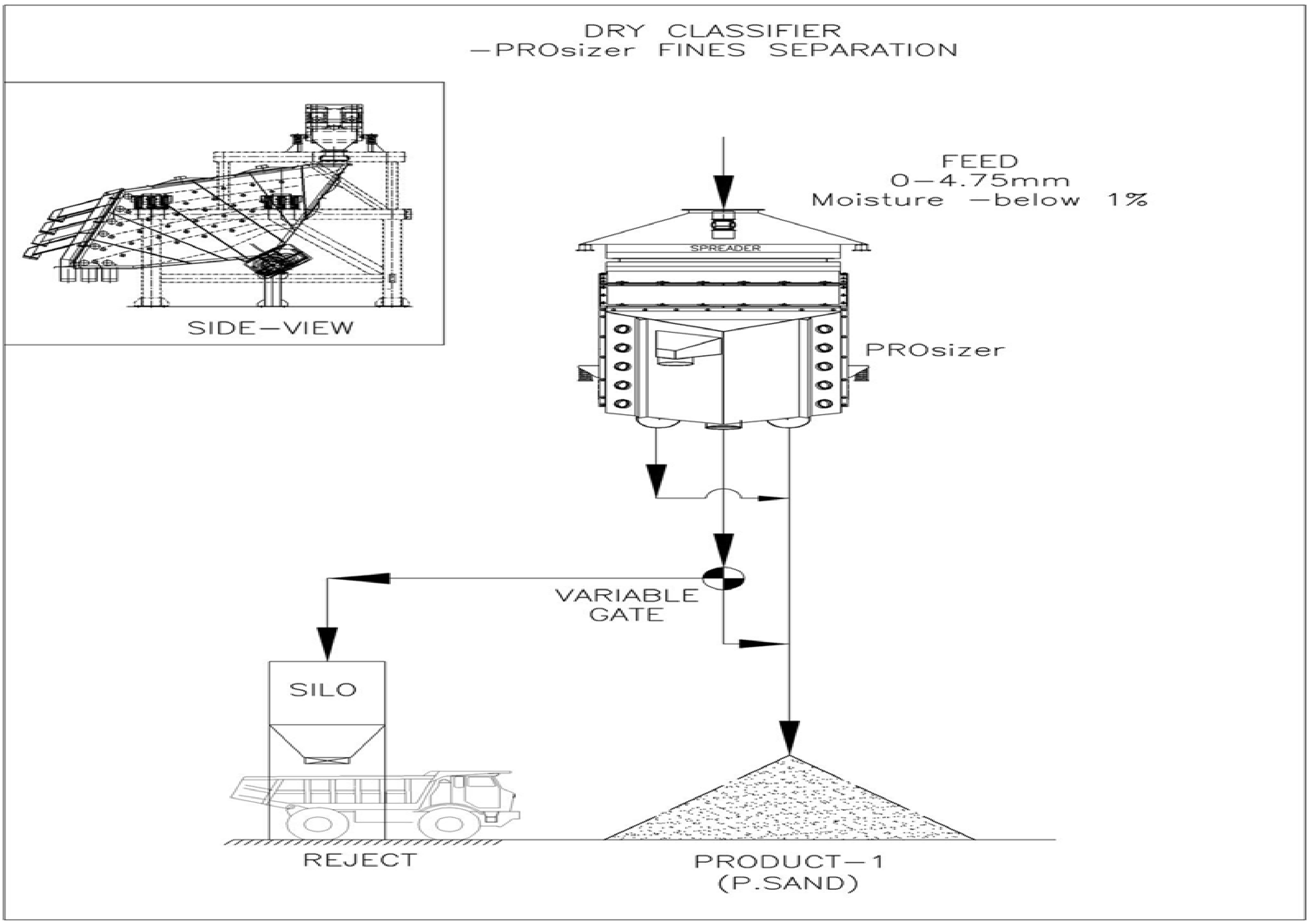
It requires an adequate water supply to operate properly. It controls the cleanliness of the sand. Make up water :160litres per ton

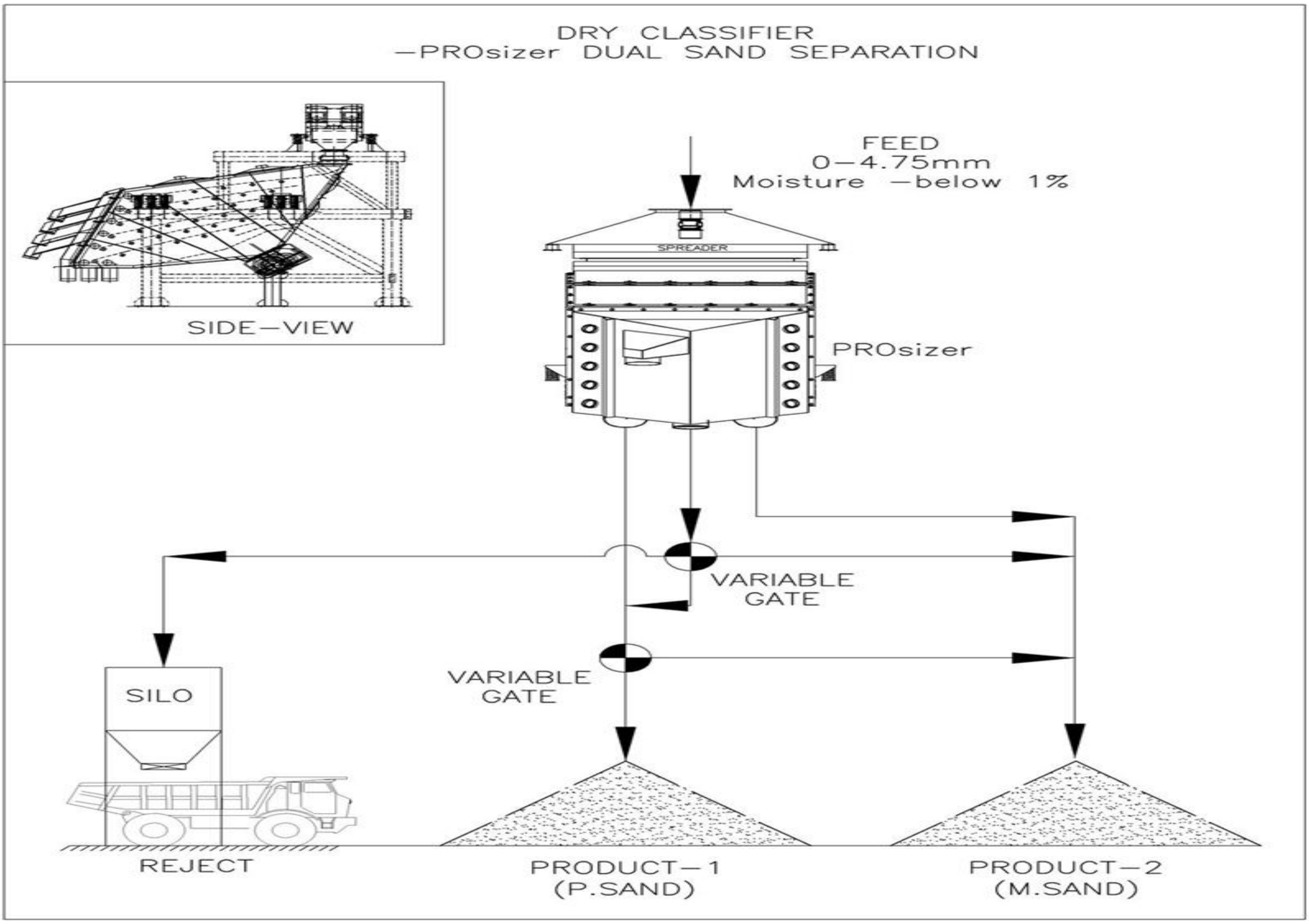
PROMAN

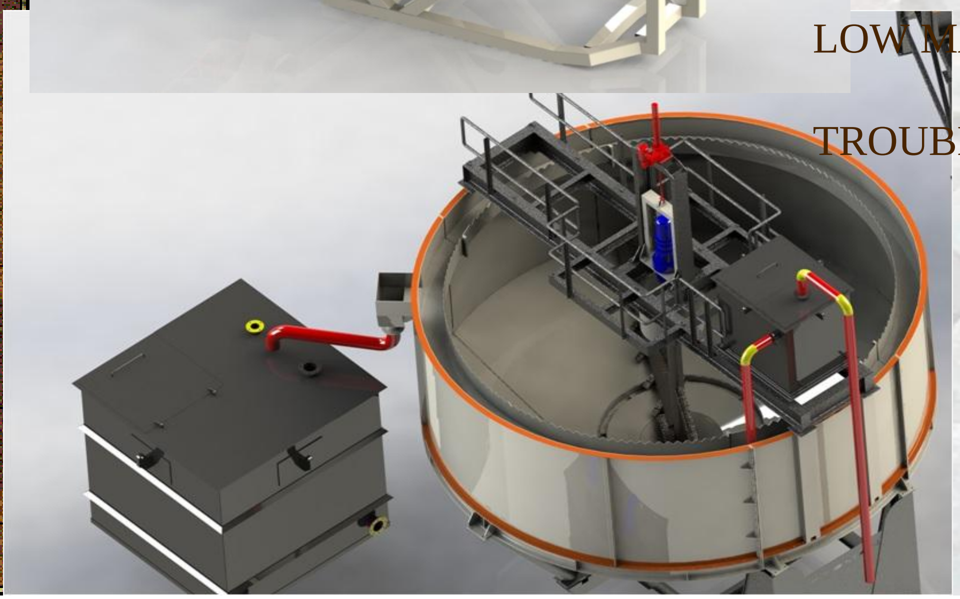
PROsizer

- High screening efficiency
- Fine screening 0.15mm to 50mm
- Low power
- Simple service
- Dust proof system

PROMAN







PROMAN WSG

WASHED SAND

COMPACT DESIGN

CUTTING FINES AT DESIRED LEVEL

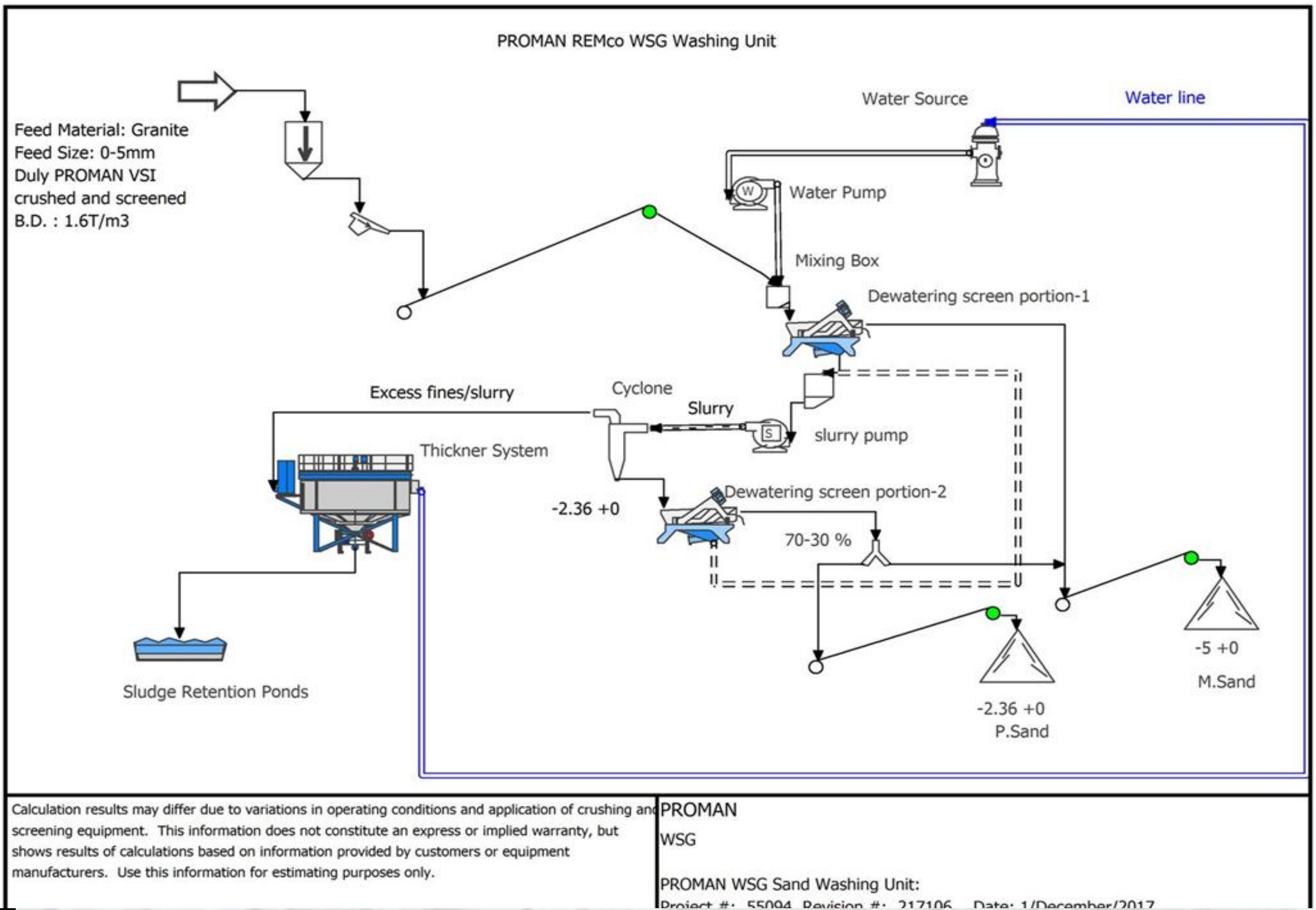
MAXIMUM WATER RECOVERY

LOW MAINTENANCE

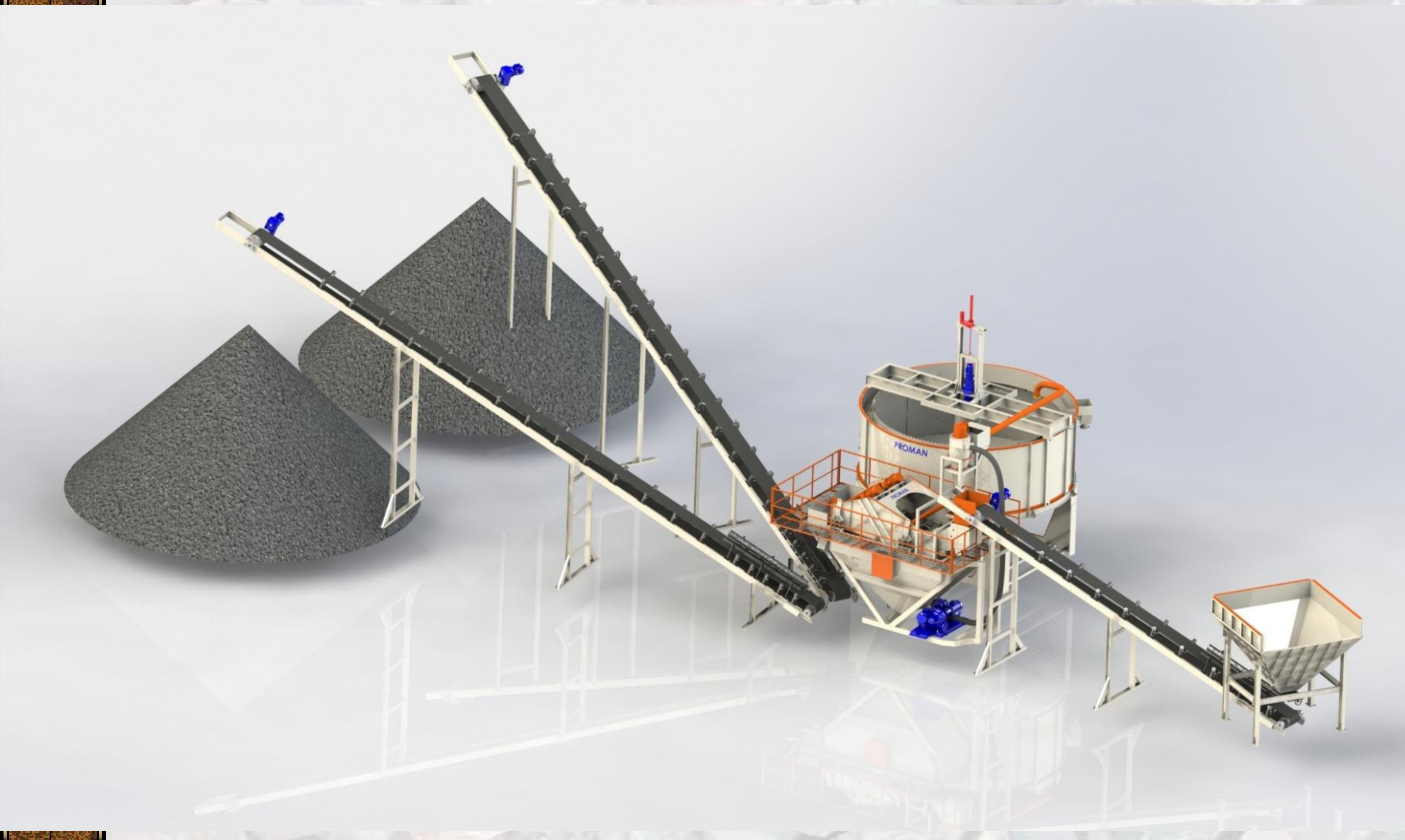
TROUBLE FREE OPERATION

PROMAN

Process Flow Sheet WSG



PROMAN WSG DUAL SAND UNIT

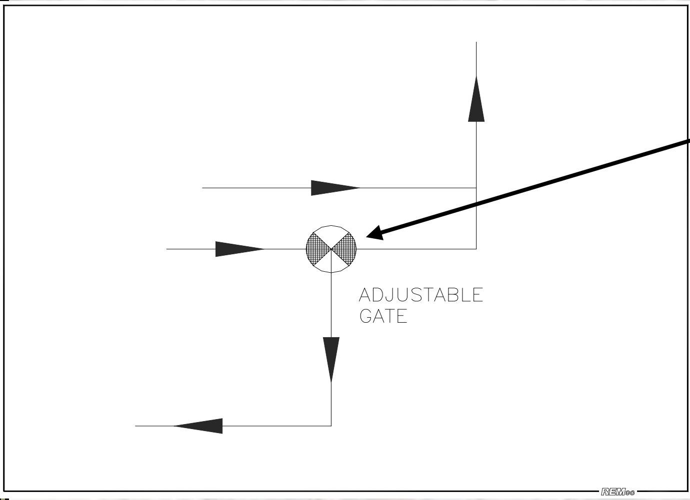


PROMAN

How Do We Build A Spec Sand Manufacturing Circuit?

- We start with a surge.
- We add a feeder.
- We include automation.
- We select a proper screen.
- Add a Fines classifier.
- Add blending gates to the circuit.

PROMAN

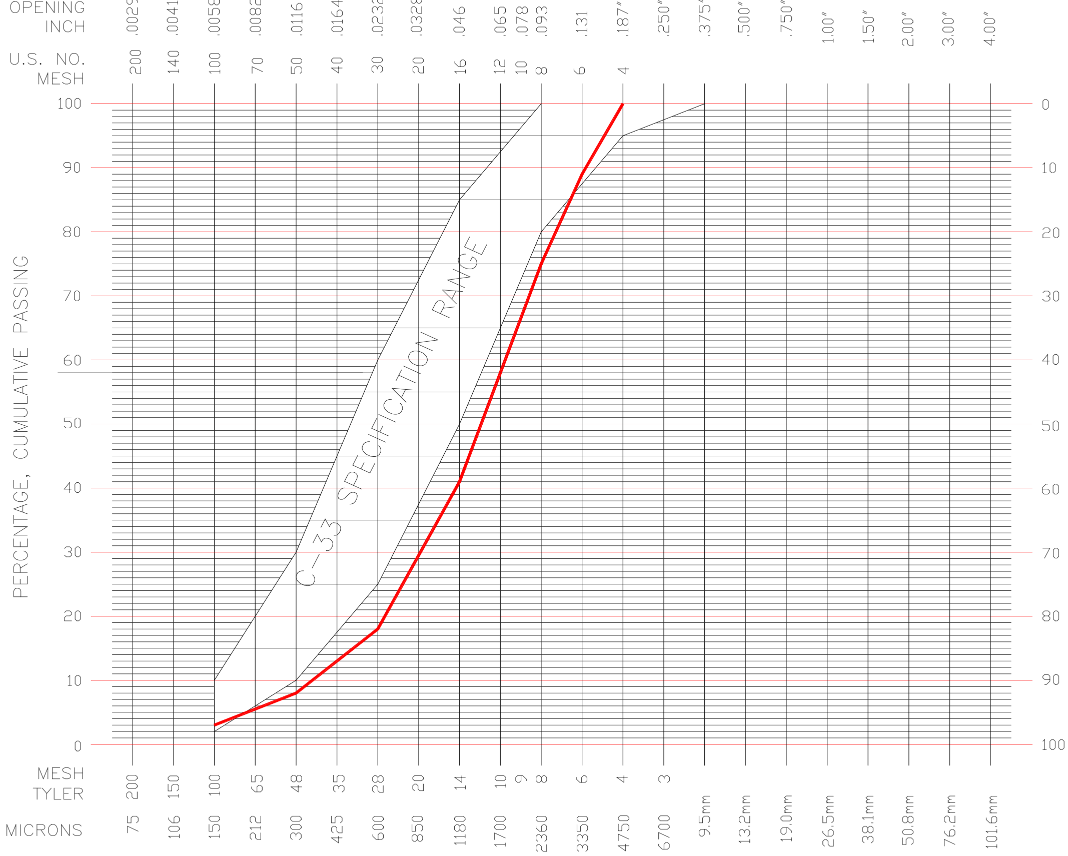


A portion of the material retained on the lower deck can be put to product and the excess returned to the crusher.

Blending gates are positioned at the discharge lips of the screen.

Blending gates are a key feature of a sand circuit to control fineness or coarseness of the final sand grading.

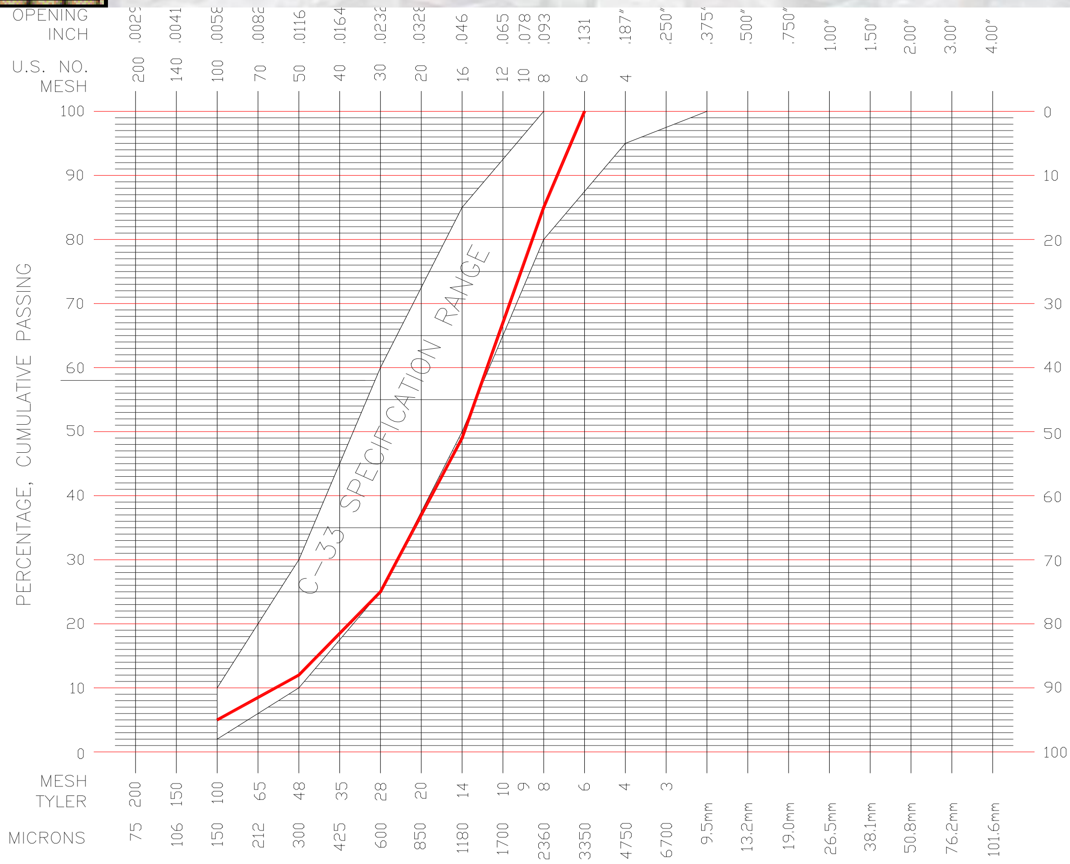
PROMAN



SIEVE SIZE	C-33 SPEC.	-4 MESH PRODUCT
3/8" (9.5mm)	100	
1/4" (6.7mm)		
4M (4.75mm)	95-100	100
6M (3.55mm)		89
8M (2.36mm)	80-100	75
16M (1.18mm)	50-85	41
30M (.60mm)	25-60	18
50M (.30MM)	10-30	8
100M (.15mm)	2-10	3
200M (.075mm)	0-5	

Minus 4m (4.75mm) out of specification sand.

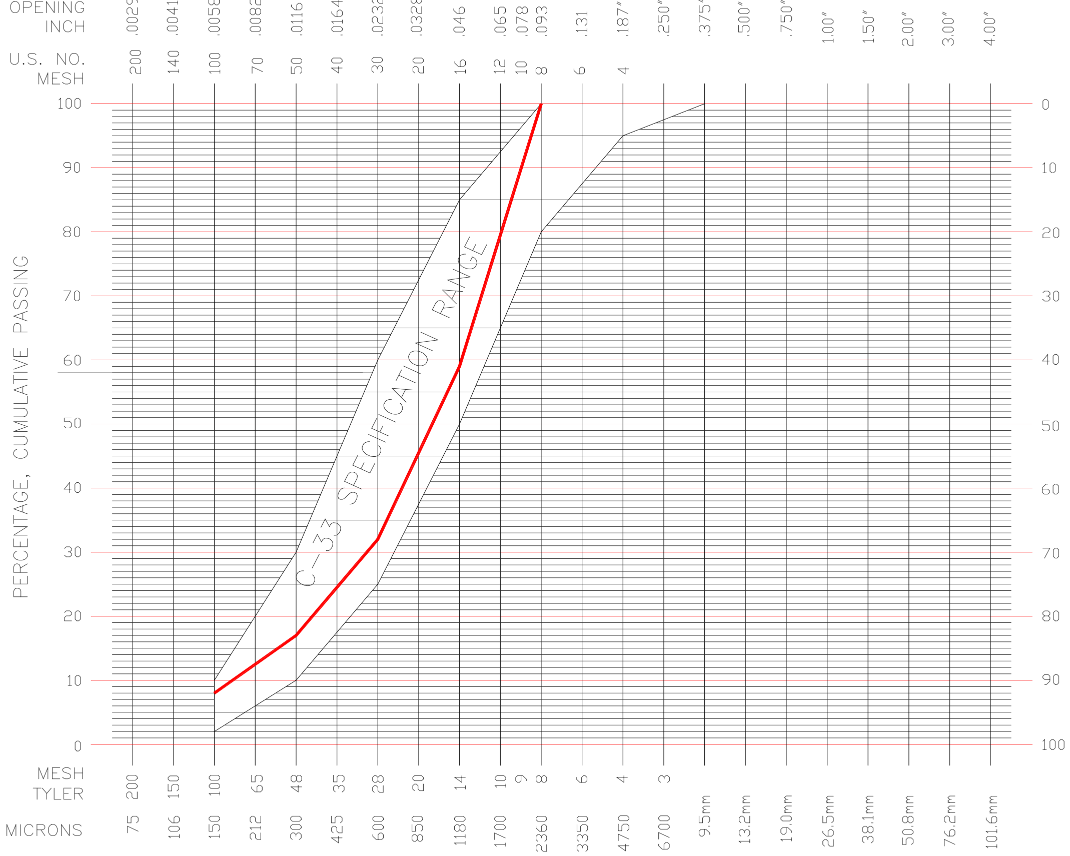
PROMAN



SIEVE SIZE	C-33 SPEC.	-6 MESH PRODUCT
3/8" (9.5mm)	100	
1/4" (6.7mm)		
4M (4.75mm)	95-100	
6M (3.55mm)		100
8M (2.36mm)	80-100	85
16M (1.18mm)	50-85	49
30M (.60mm)	25-60	25
50M (.30MM)	10-30	12
100M (.15mm)	2-10	5
200M (.075mm)	0-5	

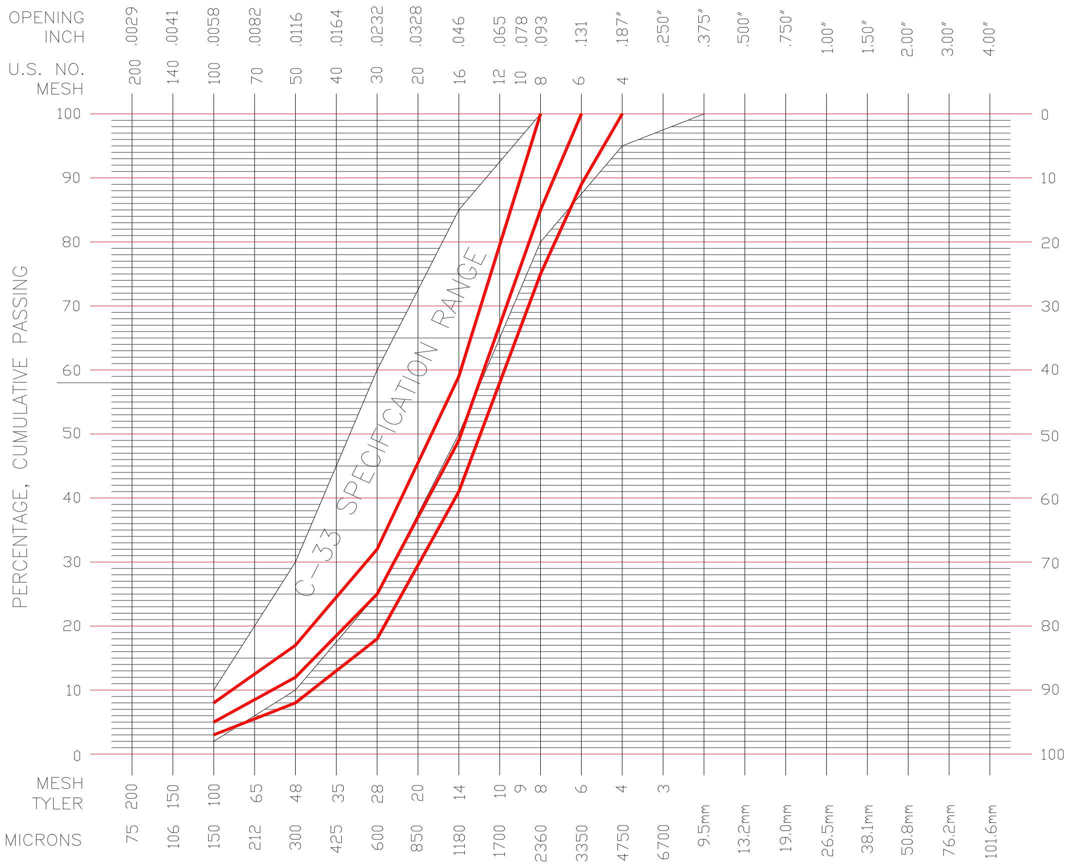
Improved grading by reducing screen opening and use of blending gates.

PROMAN



SIEVE SIZE	C-33 SPEC.	-8 MESH PRODUCT
3/8" (9.5mm)	100	
1/4" (6.7mm)		
4M (4.75mm)	95-100	
6M (3.55mm)		
8M (2.36mm)	80-100	100
16M (1.18mm)	50-85	59
30M (.60mm)	25-60	32
50M (.30MM)	10-30	17
100M (.15mm)	2-10	8
200M (.075mm)	0-5	

In specification sand grading by reducing screen opening and rejecting the 4m x 8m (4.75mm x 2.36mm) back to the crusher.

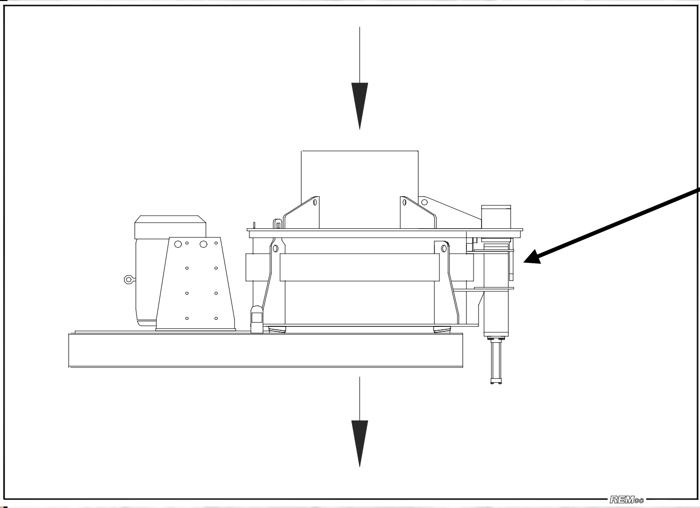


SIEVE SIZE	C-33 SPEC.
3/8" (9.5mm)	100
1/4" (6.7mm)	
4M (4.75mm)	95-100
6M (3.55mm)	
8M (2.36mm)	80-100
16M (1.18mm)	50-85
30M (.60mm)	25-60
50M (.30MM)	10-30
100M (.15mm)	2-10
200M (.075mm)	0-5

Illustration showing the progressive adjustment of the sand grading into the C-33 range.

How Do We Build A Spec Sand Manufacturing Circuit?

- We start with a surge.
- We add a feeder.
- We include automation.
- We select a proper screen.
- Add a sand washing\dewatering screw.
- Add blending gates to the circuits.
- Add a PROMAN REMco SandMax VSI.

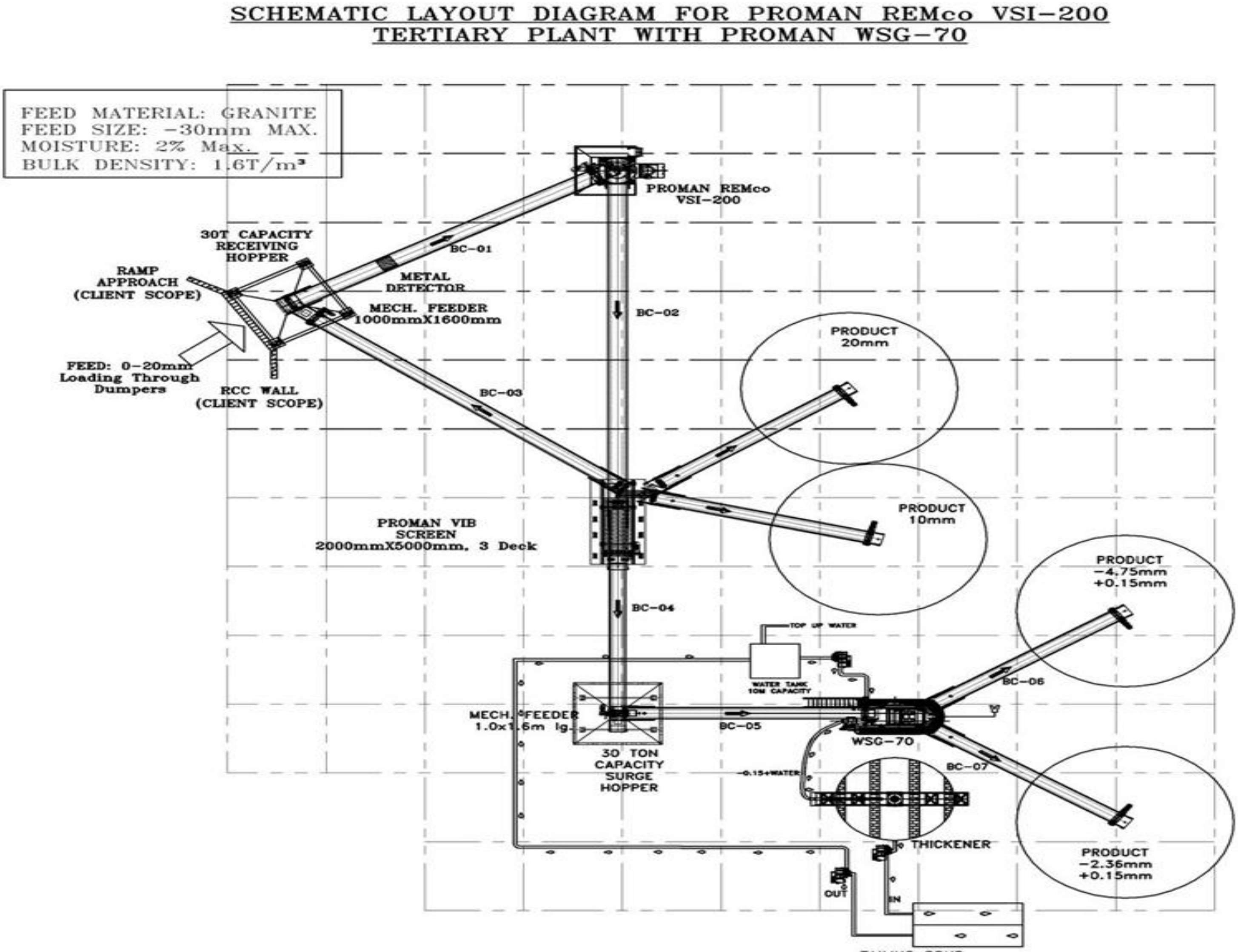


PROMAN REMco SandMax crushers have full hydraulic access for easy inspection and service.

The PROMAN REMco SandMax is an impact crusher exclusively designed to produce sand and other fine products.

It will produce manufactured C-33 sand from hard abrasive rock for an affordable cost.

REMco SandMax crushers come in 8 sizes with drive power 60 hp to 1500 hp.



Custom Sand Circuits Possible

With your material information a PROMAN REMco SandMax system can be custom engineered to meet your sand production requirements.

Forget the idea of simply adding a VSI to your existing circuit to make sand. It takes more than a crusher. **It requires a complete circuit for successful manufactured sand production at a low cost.**

DRY MORTAR

WHAT IS DRY MORTAR

Basically, it is the mixture of cement, lime, additives and aggregates of granulometry not exceeding 4 mm (Sand).

Advantage

- Reduction of manufacturing and indirect costs, labor and auxiliary equipment.

- Decrease in the work space dedicated to collection and materials sectoring.

- Protection of Material against external agents.

- Keep area clean by avoiding volatility of powders, aggregates, etc.

• Absence of waste, each moment is produced what is to be consumed.

• Reduce management work and order entry (cement, aggregates, additives, etc.).

• Immediate manufacturing, simple and automated.

• Do not requires retardant neither additional additives to keep mortar workable, all this due its instant manufacturing.

• Possibility to include color in the material.

• High durability product

COMMON MORTARS

PLASTER

he most important mortars are the rendering ortars, designed for plastering or coating the alls. These mortars can be made of cement, me, gypsum or mixed, depending on the haracteristics to be achieved: hardness, npermeability, plasticity and adhesion.

The plaster can be manufa with different characteris depending on the applica

- Fine or thick layer
- Indoor or outdoor
- Water rain proof
- Different strengh

The plaster can be spray-on by pumping equipment

MASONARY MORTAR

Special MORTAR

MARBLE FIXING

OTHER SPECIAL MORTARS

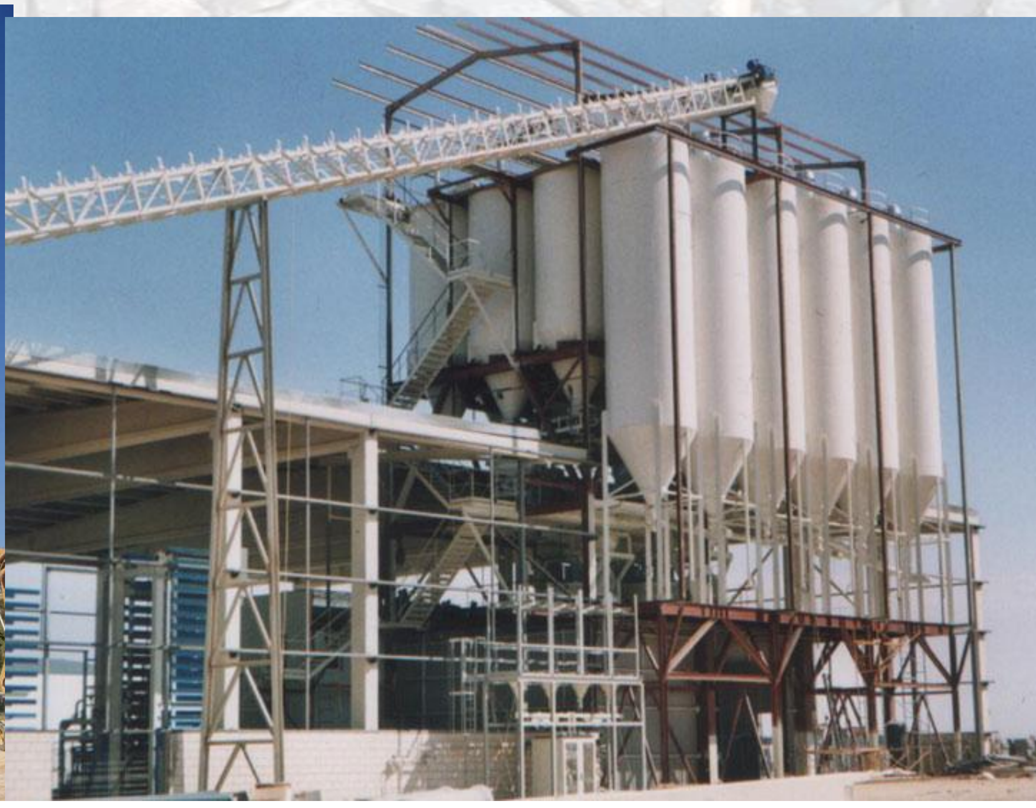
WATER-
REPELENT

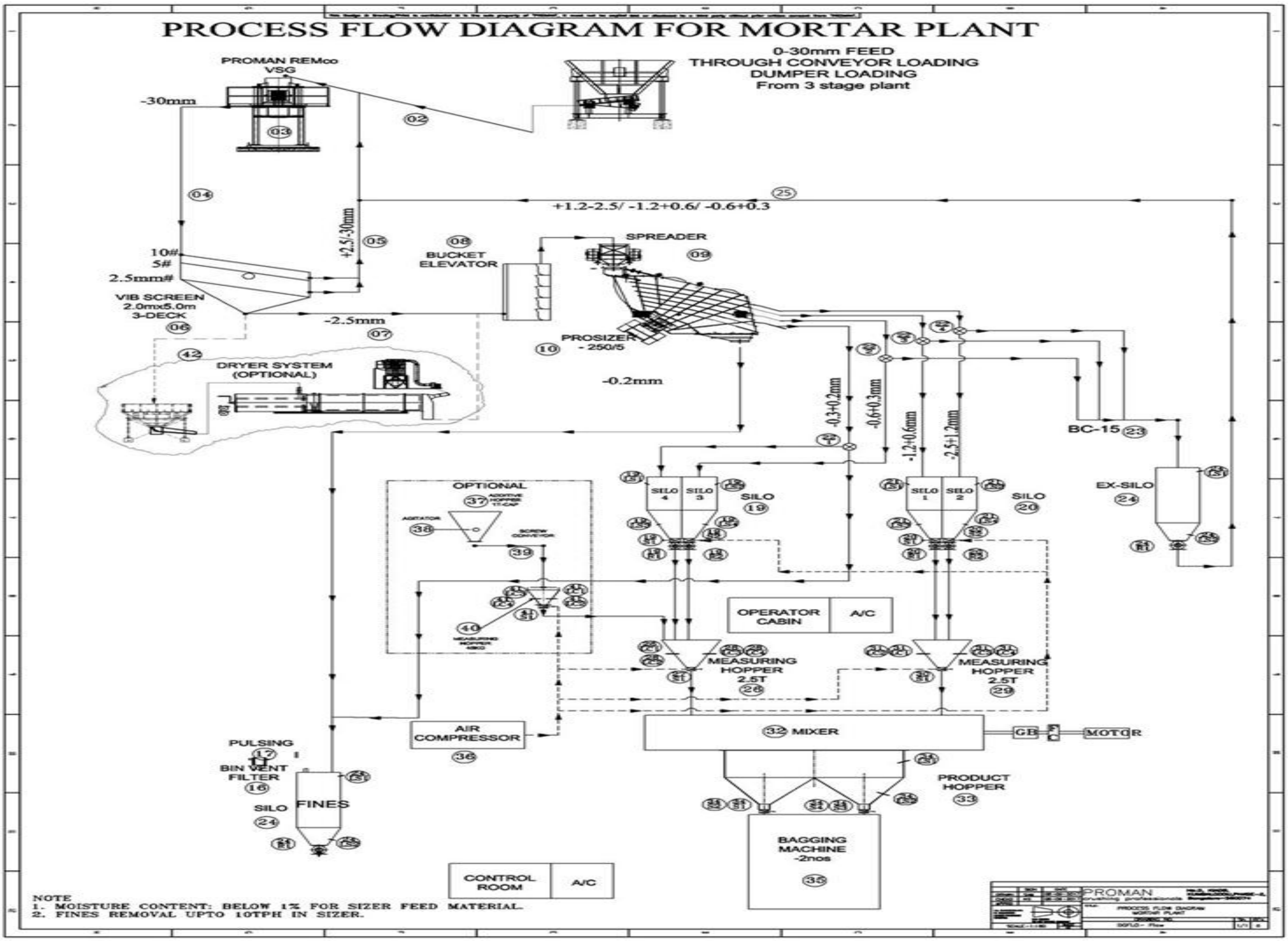
SELF LEVELING

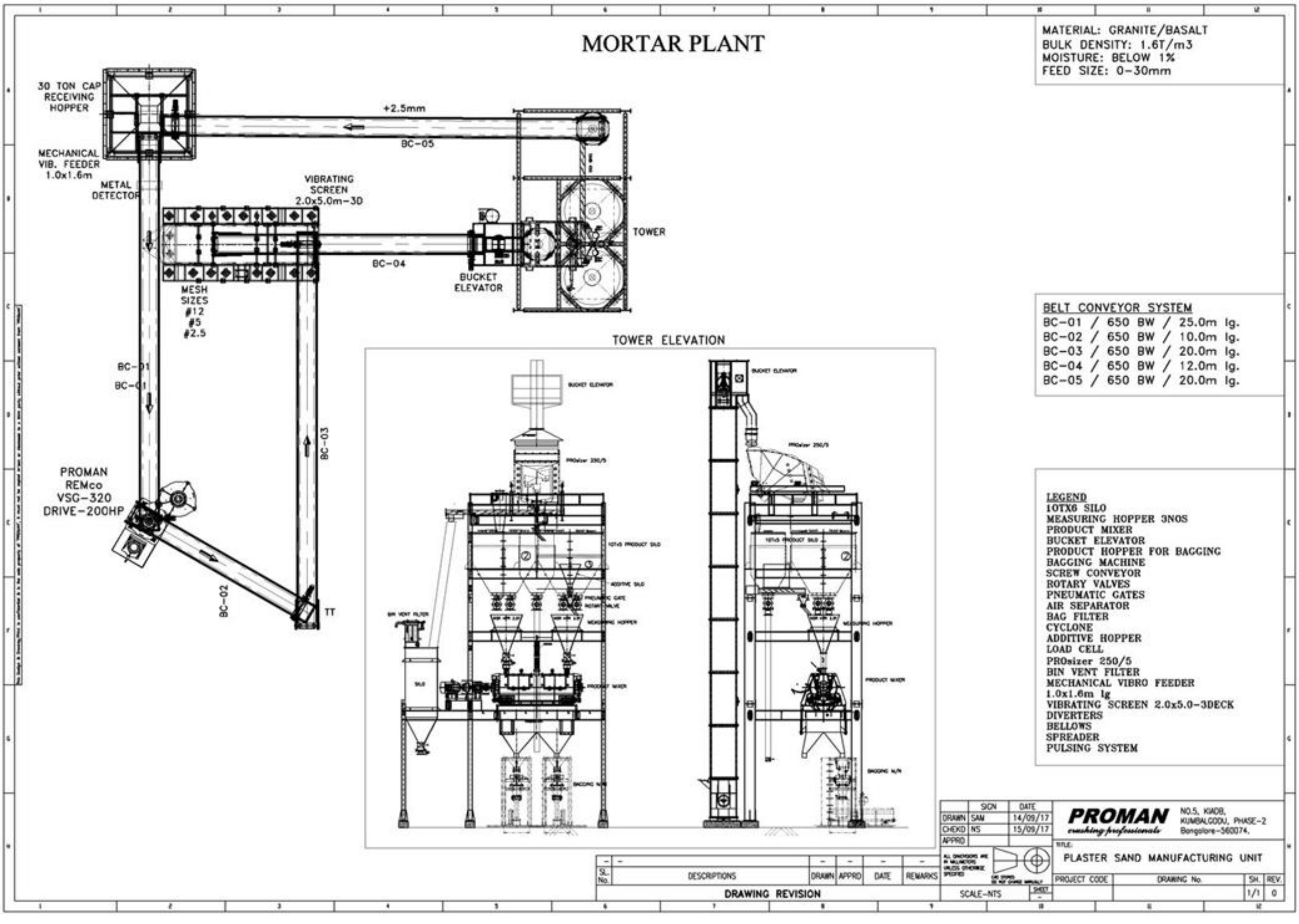
INSULATION

COLOR MONOLAYER
PLASTER

MORTAR PLANT




PROCESS FLOW DIAGRAM FOR MORTAR PLANT
0-30mm FEED
THROUGH CONVEYOR LOADING
DUMPER LOADING
From 3 stage plant
PROMAN REMco
VSG
-30mm
+1.2-2.5/ -1.2+0.6/ -0.6+0.3
+2.5/-30mm
10#
5#
2.5mm#
VIB SCREEN
2.0mx5.0m
3-DECK
-2.5mm
BUCKET
ELEVATOR
SPREADER
PROSIZER
- 250/5
-0.2mm
DRYER SYSTEM
(OPTIONAL)
-0.3+0.2mm
-0.6+0.3mm
-1.2+0.6mm
-2.5+1.2mm
BC-15
EX-SILO
OPTIONAL
AGITATOR
SILO
OPERATOR
CABIN
A/C
MEASURING
HOPPER
2.5T
AIR
COMPRESSOR
MIXER
GB
MOTOR
PULSING
BIN VENT
FILTER
SILO
FINES
PRODUCT
HOPPER
BAGGING
MACHINE
-2nos
CONTROL
ROOM
NOTE
1. MOISTURE CONTENT: BELOW 1% FOR SIZER FEED MATERIAL.
2. FINES REMOVAL UPTO 10TPH IN SIZER.
PROMAN


MORTAR PLANT
MATERIAL: GRANITE/BASALT
BULK DENSITY: 1.6T/m3
MOISTURE: BELOW 1%
FEED SIZE: 0-30mm
30 TON CAP
RECEIVING
HOPPER
+2.5mm
BC-05
MECHANICAL
VIB. FEEDER
1.0x1.6m
METAL
DETECTOR
VIBRATING
SCREEN
2.0x5.0m-3D
BC-04
BUCKET
ELEVATOR
TOWER
MESH
SIZES
#12
#5
#2.5
BC-01
BC-03
PROMAN
REMco
VSG-320
DRIVE-200HP
BC-02
TT
TOWER ELEVATION
BELT CONVEYOR SYSTEM
BC-01 / 650 BW / 25.0m lg.
BC-02 / 650 BW / 10.0m lg.
BC-03 / 650 BW / 20.0m lg.
BC-04 / 650 BW / 12.0m lg.
BC-05 / 650 BW / 20.0m lg.
LEGEND
10TX6 SILO
MEASURING HOPPER 3NOS
PRODUCT MIXER
BUCKET ELEVATOR
PRODUCT HOPPER FOR BAGGING
BAGGING MACHINE
SCREW CONVEYOR
ROTARY VALVES
PNEUMATIC GATES
AIR SEPARATOR
BAG FILTER
CYCLONE
ADDITIVE HOPPER
LOAD CELL
PROsizer 250/5
BIN VENT FILTER
MECHANICAL VIBRO FEEDER
1.0x1.6m lg
VIBRATING SCREEN 2.0x5.0-3DECK
DIVERTERS
BELLOWS
SPREADER
PULSING SYSTEM
SIGN
DATE
DRAWN SAN 14/09/17
CHEKD NS 15/09/17
APPRD
PROMAN
crushing professionals
NO.5, KIADB,
KUMBALGODU, PHASE-2
Bangalore-560074.
TITLE:
PLASTER SAND MANUFACTURING UNIT
PROJECT CODE
DRAWING No.
SH.
REV.
1/1
0
SL.
No.
DESCRIPTIONS
DRAWN
APPRD
DATE
REMARKS
DRAWING REVISION
SCALE-NTS

SUPPLY IN BAGS AND SACKS

Mortars are supplied in bags or sacks

Final mix can be done manually or using a wet mixer bag splitter

Thank you

BETTER AGGREGATES FOR CONCRETE & ALTERNATIVES TO RIVER SAND

ICI

Presented by

Mr. K Srinivasa Reddy, MD

DesignTree Service Consultants Pvt Ltd

TOPICS

- Manufactured sand / slag sand
- Crushed stone sand, plaster sand, latest revision in codal provisions
- Pond-ash as alternative to river sand
- Aggregate manufacturing machinery
- C&D WASTE (construction and demolition waste) AS AGGREGATES

CONCRETE

A composite material composed of coarse aggregate bonded together with a fluid cement that hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements, such as ciment fondu. However, asphalt concrete, which is frequently used for road surfaces, is also a type of concrete, where the cement material is bitumen, and polymer concretes are sometimes used where the cementing material is a polymer.

TYPICAL PROPERTIES OF NORMAL STRENGTH PORTLAND CEMENT CONCRETE:

- Density - ρ : 2240 - 2400 kg/m^3 (140 - 150 lb/ft^3)
- Compressive strength : 20 - 40 MPa (3000 - 6000 psi)
- Flexural strength : 3 - 5 MPa (400 - 700 psi)
- Tensile strength - σ : 2 - 5 MPa (300 - 700 psi)
- Modulus of elasticity - E : 14 - 41 GPa (2 - 6 x 10^6 psi)
- Permeability : 1 x 10^{-10} cm/sec
- Coefficient of thermal expansion - β : 10^{-5} $^oC^{-1}$ (5.5 x 10^{-6} $^oF^{-1}$)
- Drying shrinkage : 4 - 8 x 10^{-4}
- Drying shrinkage of reinforced concrete : 2 - 3 x 10^{-4}
- Poisson's ratio : 0.20 - 0.21
- Shear strength - τ : 6 - 17 MPa
- Specific heat - c : 0.75 kJ/kg K (0.18 Btu/lb_m ^oF (kcal/kg ^oC))

BETTER AGGREGATES FOR CONCRETE

EPS: Expanded Polystyrene.

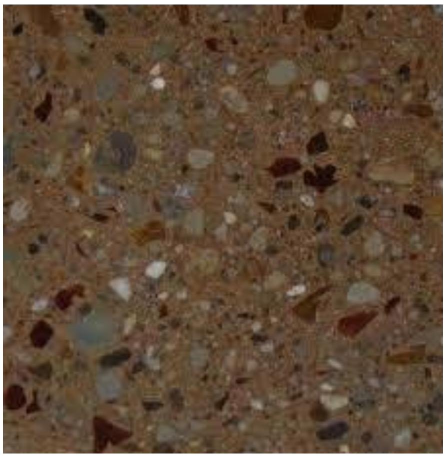
- Research has shown that concrete with this material behaves very similarly to light weight concretes containing traditional aggregates.
- This is believed to be the case because the Styrofoam fills in the gaps that would normally be filled with air. EPScrete is made using 1mm - 3mm diameter expanded polystyrene beads, sand, cement and water in the following ratio 666.6:500:233.3:1 (cement [kg/m^3]:sand [kg/m^3]:water [L/m^3]:polystyrene [m^3/m^3]).

Plastic

- High-density polyethylene can be added to concrete and sand as a feasible replacement for coarse aggregate.

GlassCrete

- Concrete with glass aggregate is a material mixture that has a lot of potential but also a lot keeping it from reaching this potential.
- Any type of glass when broken down to about #8 to #4 sieve, with compression strengths comparable to that of normal weight concrete and when glass powder has the same gluing effect as cement, Glasscrete is the best aggregate alternative of the list.

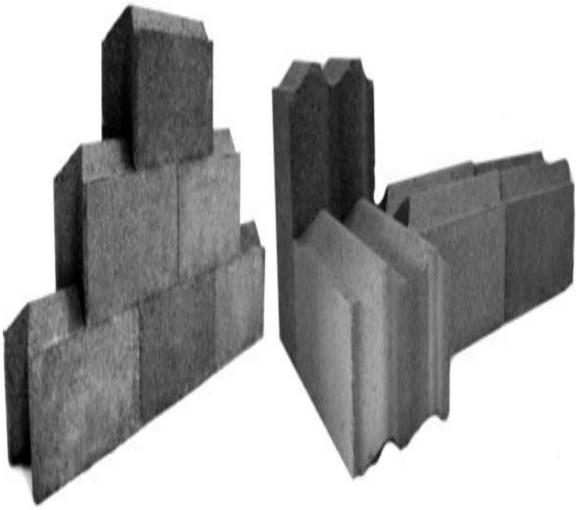


Crushed Rubber

- When vehicles tires reach the end of their usable life, they can still find some use as a replacement for course aggregate in concrete mixes.
- Crumb rubber is car or truck tires that are ground up between the sizes of 3 - 10 mm.
- This mix has very poor compressive strength due to its high air content.
- It is believed that when this rubber is mixed in with the concrete air becomes trapped in with it. One benefit to the addition of this alternative is the rubber keeps the concrete from shattering in failure.

High Density Polyethene (HDPE)

- High-density polyethylene can be added to concrete as a replacement for course aggregate. But as the name implies, the material is too ductile at full strength to support structural loads at 2500psi.
- One benefit to this material is its measurable qualities in holding heat within buildings.



MANUFACTURED SAND

- Manufactured sand is popularly known by several names such as Crushed sand, Rock sand, Green sand, UltraMod Sand, Robo sand, Poabs sand, Barmac sand, Pozzolan sand etc. IS 383-1970 (Reaffirmed 2007) recognizes manufacture sand as 'Crushed Stone Sand'.

- 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.

- Fine aggregates manufactured sand proposed to be used shall be produced from a Vertical Shaft Impact (VSI) crushers and shall conform to the requirements of Zone-II (in most of the cases) as per IS 383-1970 (Reaffirmed in 2007) and particles finer than 75 µm shall not exceed 15 %.

- M-sand can also be used for making masonry mortar and shall conform to the requirements of IS 2116-1980 (Reaffirmed 1998) – "Specification of sand for Masonry mortars".

- **General Requirements**

1. All the sand particles should have higher crushing strength
2. The surface texture of the particles should be smooth
3. The edges of the particles should be grounded
4. The ratio of fines below 600 microns in sand should not be less than 30%
5. There should not be any organic impurities
6. Silt in sand should not be more than 2%, for crushed sand
7. In manufactured sand the permissible limit of fines below 75 microns shall not exceed 15%

- **Manufactured Sand Quality**

Manufactured Sand should adhere to the highest standards and must undergo the following quality tests

1. Sieve analysis
2. Optical Microscopic Study to check the particle shape
3. Workability (slump test by slump cone method)
4. Cube test for compressive strength
5. Tests for Silt and clay

- The Indian Standard IS: 383; "Specification for Coarse and Fine Aggregates from Natural Sources for Concrete" covers the requirements for aggregates, crushed or uncrushed, derived from natural sources, such as river terraces and riverbeds, glacial deposits, rocks, boulders and gravels, for use in the production of concrete for normal structural purposes including mass concrete works.
- Before choosing any alternative one should check the technical specifications as per the BIS codes.


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
e) Service history, if any. Subject to prior agreement, the supplier shall furnish such of the following additional information, when required by the purchaser:
f) Specific gravity, g) Bulk density, h) Moisture content
i) Absorption value
j) Aggregate crushing value or aggregate impact value
k) Abrasion value,
l) Flakiness-index, m) Elongation-index, n) 3 Presence of deleterious materials
o) Potential reactivity of aggregate
p) Soundness of aggregate

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

- M-Sand is well graded and falls within Zone II specifications of IS 383. It is devoid of clay size fraction. Dust particles (of size less than 150 microns) are also well within permissible limits (<20%).

- Contains minerals like quartz and feldspar, which are inert in nature. X-Ray diffraction studies also reveal that M-Sand contains minerals from the Mica group (Muscovite, Biotite, Boromuscovite) which do not interfere with the hydration or strength development in mortar and concrete.

- Bulk density and specific gravity of M-Sand are comparable to that of river sand. The specific gravities are 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 per cubic meter.

- Compressive Strength of mortars assessed using IS 2250 standards indicate that mortars have lower water to cement ratio.

- Mortar prepared with M-Sand exhibit better flow characteristics than river sand. In fact, the mortar strength doubles when M-Sand is used instead of river sand because of its compressive strength.

- M-Sand has better water retention than river sand. Water Retentivity values for 1:6 cement mortar using river sand and M-Sand are 27.3% and 28.5% respectively. Better water retention of M-Sand results in better bond development and better strength.

- The Flexure bond strength of masonry prism improves by 150% with the usage of M-Sand.

- Stress-strain relationships generated by testing stack bonded masonry prisms built using 1:6 cement mortar reveal that M-Sand has better stress strain modulus than river sand. The initial tangent modulus of masonry for M-Sand and river sand are 1200 MPa and 500 MPa respectively. This leads to better bond between brick and mortar in M-Sand.

PLASTER SAND

- Surface area of micro fine dust is more, approximately 1 kg dust has 400 sq. Meter surface area. More dust, more surface area & more surface area means increase in water cement ratio.
- Mortar with micro fine dust shrinks after setting and develops cracks in plaster.
- Generally plaster mortar is manually mixed. Whenever crush sand made from black stone is used color of dust & cement resembles & makes wrong impression of homogeneous mix. For homogeneous mix concrete mixer have to be used but, may not be feasible every time.
- Cost effective.
- Dust free crushed plaster sand gives very good strength compare to river sand.
- Dust free sand increases workability in manual plaster.
- No impurities such as coal, bones, seeds, shells & other decaying organic materials are present in machine made plaster sand. This increases 30 % strength of the plaster. No admixture is required.

POND ASH AS ALTERNATIVE TO RIVER SAND

- In the thermal power plants the coal is burnt to heat the water for making the steam, which in turn is used to run the turbines. The pond ash is a waste product from the boilers. It is mainly obtained from the wet disposal of the fly ash, which when get mixed with bottom ash is disposed off in large pond or dykes as slurry.

Physical properties of pond ash

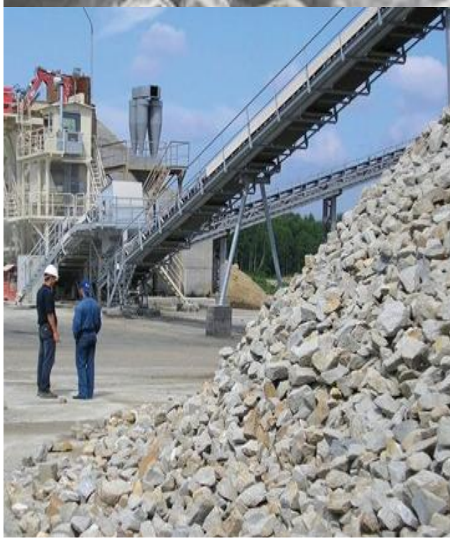
Sr.No.	*Properties*	**Pond Ash**
1.	Lime Reactivity of Pond ash	0.66
2.	Specific Gravity	2.16
3.	Bulk density in Loose State	824 kg/m^3
4.	Bulk density in Compacted State	990 kg/m^3
5.	Atterberg's Limits Liquid Limits percentage	 47.3
6.	Grain size distribution Sand % Silt % Clay %	 72 28 NIL
7.	IS Classification	SP-SM

Chemical Composition of pond ash

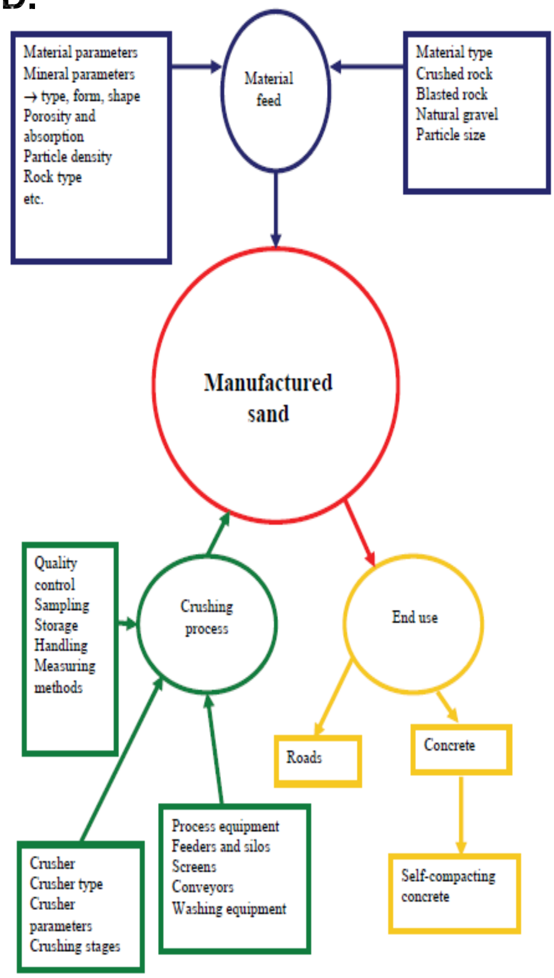
Constituent	Fly ash (%)	Pond ash (%)
Silica (SiO_2)	49 – 67	67.40
Alumina (Al_2O_3)	16 – 29	19.44
Iron Oxide (Fe_2O_3)	4 – 10	8.5
Calcium Oxide (CaO)	1 – 4	2.7
Magnesium Oxide (MgO)	0.2 – 2	0.45
Sulphur (SO_3)	0.1 – 2	0.30
Loss of Ignition	0.5 – 3	3.46

AGGREGATES MANUFACTURING MACHINERY

- **Hydro hammer**
- **Belt Conveyor**
- **Compression crushers**
  - ✓ **Jaw crushers**
  - ✓ **Gyratory crusher**
  - ✓ **Roll crushers**
- **Impact crushers**
  - ✓ **Swinghammer crushers**
  - ✓ **Impact crushers with fixe blow-bars**
  - ✓ **Vertical shaft impactors**

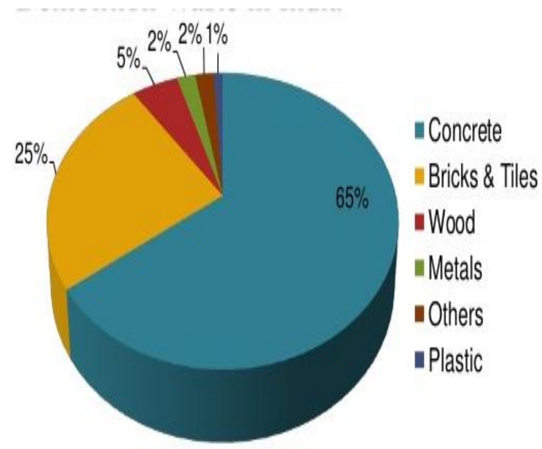


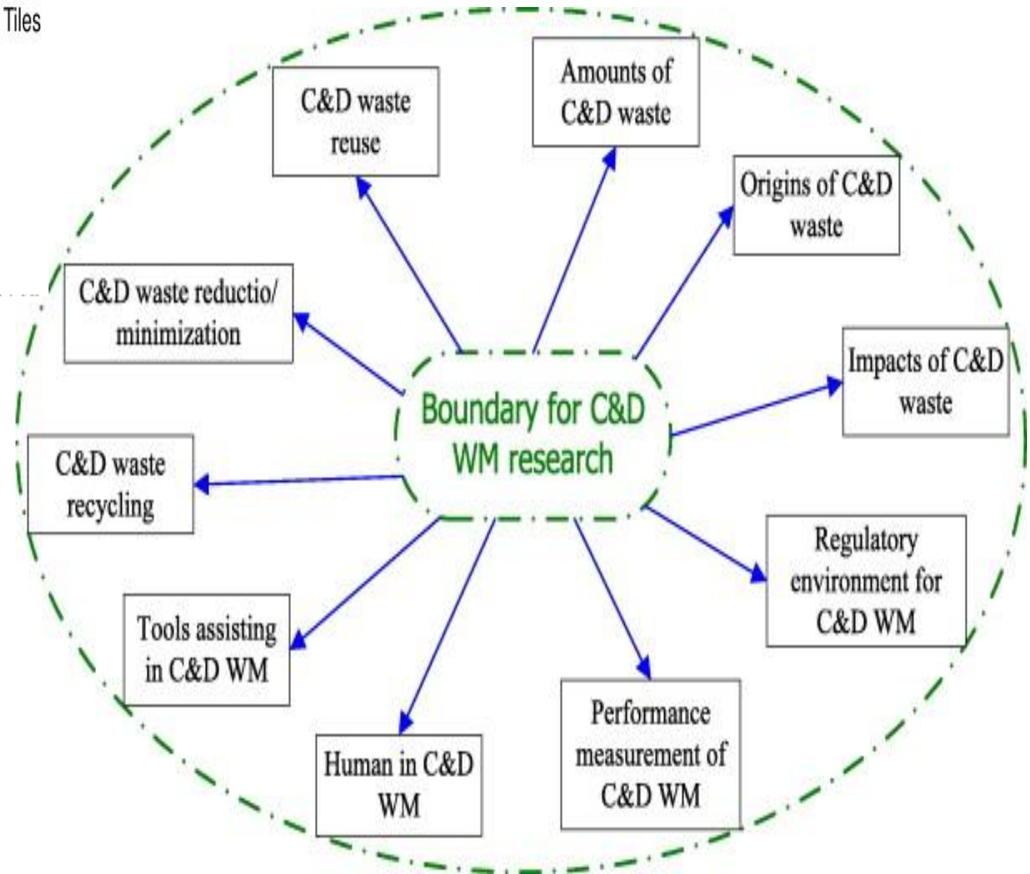
FLOW CHART SHOWING SOME OF THE FACTORS AFFECTING QUALITY OF MANUFACTURED SAND.



C&D WASTE AS AGGREGATES

- The recycling of construction materials like concrete, timber, glass, plastic & steel is primarily an attempt to reduce the cost of production of new materials and construction and also reduce the consumption of natural resources.





Country	Amount, per year	Year	Reference
Germany	223	2003	1
Australia	19	2008 - 09	5
China	200	2005	6
Japan	85	2000	6
	77	2012	7
South Korea	61.7	2013	8
Ireland	11	2004	9
Norway	1.5	2003	10
India	14.7	2001	6 (Quoting MoEF)
	10 - 12	2012	3,4

Table 1: C&D Wastes in Various Countries (Million Tonnes)

Influence of RCA on Properties of Concrete

- Fine fractions of RCA are not encouraged as replacement of fine aggregate (sand). However, it is used in many countries.
- Flexural strength and modulus of elasticity of RCA concrete are proportional to compressive strength. Typical relationships as given in design codes are compatible with the use of RCA.
- Drying shrinkage and creep of RCA concrete may be higher than in natural aggregate concrete. However, the values seldom fall outside the limit permitted in structural codes, and up to 20% replacements can give comparable results as in natural aggregate concrete.
- RCA concrete tends to be less resistant to those deleterious reactions which are dependent on fluid transport into concrete, mainly as a result of increased permeability. Chloride ingress is more rapid. Abrasion resistance is lower.
- RCA concrete has, however, better resistance to carbonation than natural aggregate concrete.

THANK YOU

BETTER AGGREGATES FOR CONCRETE & ALTERNATIVES TO RIVER SAND

By Mr. Syed Nafeesuddin,
Cluster Quality Head, L&T, B&F IC

Date: 7th Dec'17

AGENDA

- *Introduction on Concrete*
- *Aggregates & it's characteristics*
- *Replacement to River Sand - Manufactured Sand*
- *Replacement to River Sand & Manufactured Sand - Processed Granulated Blast Furnace Slag*
- *Conclusion*

INTRODUCTION ON CONCRETE

CONCRETE

Basic Definition:

Concrete is a composite material that essentially consists of water, a binding medium embedded with Fine-Aggregate (typically sand) and Coarse Aggregate (typically gravel) with or without chemical and mineral admixture and filler.

Constituents:

Mixture of Aggregate and Paste

Paste 30 to 40%

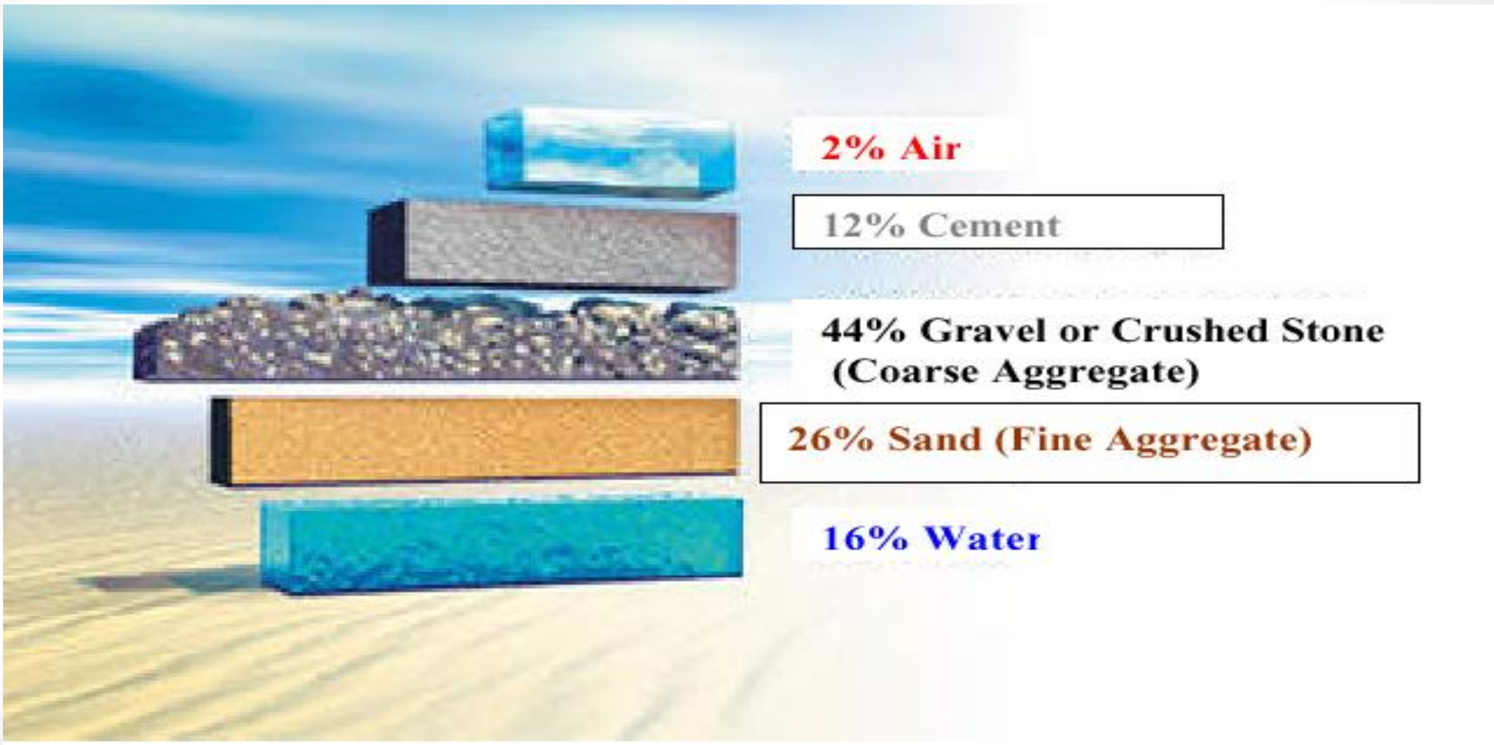
- Cementitious 7% to 15% by Vol.
- Water 14% to 21% by Vol.

Aggregates 60% to 70%

- Coarse aggregates

CONCRETE

Typical Concrete Proportion by Volume

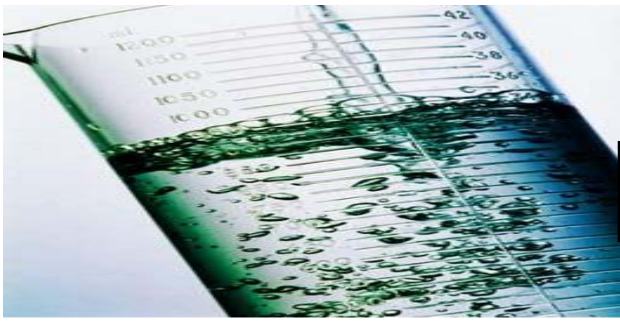


BASIC CONCRETE COMPONENTS


Cement


Coarse Aggregate


Natural Sand


Water

AGGREGATES & IT'S CHARACTERISTICS

BASIC FUNCTIONS OF AGGREGATE

LARSEN & TOUBRO

Basic functions of aggregate,

- **Cheap fillers**
- **Hard material**
- **Provide volume stability**
- **Reduce volume changes**
- **Provide abrasion resistance**

Aggregate is relatively inexpensive and does not enter into complex chemical reactions with water; it has been customary, therefore, to treat it as an inert filler in concrete.

However, due to increasing awareness of the role played by aggregates in determining many important properties of concrete, the traditional view of the aggregate as an inert filler is being seriously questioned.

It is inappropriate to treat the aggregate with any less respect than cement as it occupies 60 – 70% Volume in a concrete formulation .

TECHNOLOGY | ENGINEERING | MANUFACTURING | CONSTRUCTION

NOMENCLATURE & CLASSIFICATION

For the most part, concrete aggregates are comprised of sand, gravel, and crushed rock derived from natural sources and, therefore, are referred to as **natural mineral aggregates** (are further classified as granite, limestone, basalt etc. depending upon their parent rock source)

On the other hand, thermally processed materials such as expanded clay and shale, which are used for making lightweight concrete, are called **synthetic aggregates**. Aggregates made from industrial by-products, for instance, blast-furnace slag and fly ash, also belong to this category.

AGGREGATE CHARACTERISTICS

- Generally, aggregate properties affect not only the concrete mixture proportions but also the behavior of fresh and hardened concrete.
- Due to considerable overlap between the two, it is more appropriate to divide the study of aggregate properties into three categories that are based on micro structural and processing factors.

Characteristics dependent on porosity: density, moisture absorption, strength, hardness, elastic modulus, and soundness

Characteristics dependent on prior exposure and processing factors: particle size, shape, and texture

Characteristics dependent on chemical and mineralogical composition: strength, hardness, elastic modulus, and deleterious substances presence

Cont…

AGGREGATE CHARACTERISTICS

A knowledge of certain aggregate characteristics (i.e., density, grading, and moisture state) is required for proportioning concrete mixtures. Porosity or density, grading, shape, and surface texture determine the properties of plastic concrete mixtures.

The mineralogical composition of aggregate affects its crushing strength, hardness, elastic modulus, and soundness which, in turn, influence various properties of hardened concrete containing the aggregate.

LARSEN & TOUBRO

REPLACEMENT TO RIVER SAND - MANUFACTURED SAND

RIVER SAND

The most commonly used aggregate is river sand collected from river bed but presently has availability and quality issues. The natural sand deposits are depleting and illegal sand mining is becoming uncontrollable. Even after the receipt of river sand, we find increased silt content, organic impurities & % fines which alters the quality of concrete. Cost of river sand is also too high.

Hence decisive steps have to be taken and alternate solutions to be found for sand mining, without disturbing the environment.

One of such alternate solution is use of **Crusher Sand/ Manufactured sand**.

CRUSHER SAND/ MANUFACTURED SAND

CRUSHER SAND:

Crusher sand obtained from crushing stones/rocks. It cannot be directly replaced for fine aggregate as it doesn't confirm to the requirement of IS 383:2016. In simpler plant configurations the quarry raw feed, even when the raw feed is selected on some basis of quality, is processed through two, three or four stages of crushing and shaping and then is separated into a variety of sized aggregates.

MANUFACTURED SAND:

Manufactured sand is a further development in the use of crushed fine aggregate, resulted in replacing River sand by 100%. Like any other component of concrete, manufactured sand must be controlled by specification that is suited to the end performance required of the concrete. It is the specification and the process that must be developed at each source to comply with the specification that will distinguish manufactured sand from other products developed from crushed fine aggregate.

COMPARISON IN GRADATION

IS Sieve Size (mm)	RIVER SAND % Passing	M-SAND % Passing	% Passing for single sized aggregates of Normal Sand (IS 383 - 2016) - Zone II
10	100	100	100
4.75	100	100	90 to 100
2.36	99.7	90.7	75 to 100
1.18	89	66.2	55 to 90
600	60.9	39.8	35 to 59
300	17.7	25.5	08 to 30
150	3.1	9.9	0 to 10
Remarks	**Zone II**	**Zone II**	

Ref:

https://www.nbmcw.com/concrete/28675-use-of-manufactured-sand-in-concrete-and-construction-an-alternate-to-river-sand.html

COMPARISON IN TECHNICAL SPECIFICATIONS

Properties	River Sand	Manufactured Sand	Remarks
Gradation	Cannot be controlled	Can be controlled	*Reduction in Voids and Higher strength*
Grading Zone (IS 383)	Mostly confirms Zone I & Zone II	Manufactured to conform to Zone II	*Zone II ideal for Concrete*
Particle passing 75micron	Up to 3% (IS:383-2016)	Up to 10% (IS:383-2016)	*Up to 3% for uncrushed sand and Up to 10% for Manufactured sand (As per IS 383:2016)*
Clay and Organic impurities	Likely to be present (retard the setting & compressive strength)	Absent	*Alters Concrete Quality*
Bulk Density, kg/m3	1300 - 1600	1600-1750	
Specific Gravity	2.3 - 2.8	2.5-2.9	*May vary accordingly*
Water Absorption, %	1.5-3%	2-4%	*Limit 2%*

COMPARISON IN ORGANIC IMPURITIES

DESCRIPTION	RIVER SAND	M-SAND	Remarks
Marine Products	2 - 4 %	Nil	Presence will alter the concrete quality
Oversized Materials	6 - 10 %	Nil	
Clay & Silt	5 - 20 %	Nil	

COMPARISON IN COMPRESSIVE STRENGTH

Fine Aggregates used	Workability Slump (mm)	28th day Strength (N/mm^2)
For M30, 100% River Sand	80	42.2
For M30, 100% Manufactured Sand	**55**	**44.78**

Ref:
http://khanija.kar.ncode.in/DCPublication/Suitability%20of%20Manufacture%20Sand%20(M-Sand)%20as%20fine%20aggregate%20in%20mortars%20and%20concrete.pdf

DESCRIPTION	RIVER SAND	MANUFACTURED SAND	REMARKS
Environmental Impact	Yes	**Yes but to some extent**	
Strength	As designed	**Higher than River sand (100% replacement)**	
Availability	Not easily available	**Available (Temporary solution)**	
Economy	Higher price	**Very economical than River sand**	
Workability & its retention	Good & Good retention	**Less & Less retention**	*Control of fines & apply water absorption correction, use of plasticizers*
Pump able Concrete	Easily pump able with minimum wear/tear	**Not easily pump able with wear/tear to large extent**	

REPLACEMENT TO RIVER SAND – PROCESSED GRANULATED BLAST FURNACE SLAG (PGBS)

GRANULATED BLAST FURNACE SLAG:

With restrictions on indiscriminate dredging of river sand and stone crushing there has been a growing need in civil fraternity for identification of alternative fine aggregates. One promising alternative has been granulated slags generated in steel plants, but were limited to partial replacements due to property variations. Granulated blast furnace slag (GBS) is physically similar to sand but has low density and has strength issues when used in concrete.

PROCESSED GRANULATED BLAST FURNACE SLAG:

In the present work a new processing technique has been developed to convert this slag into fine aggregate to be used as 100 % replacement to river sand, for construction purpose. This multiple stage processing involves change in structure and shape of the slag granules.

Cont…

PROCESSED GRANULATED BLAST FURNACE SLAG LARSEN & TOUBRO

Strength, durability and workability of the concrete casted with processed granulated blast furnace slag (PGBS) were found to meet the standard requirements of the cube tests. This innovative processed granulated blast furnace slag or slag sand is an economically viable and environmentally acceptable alternative material for replacing river sand having tremendous economic impact, conservation of natural resources and gainful re-cycling of process by-products.

TECHNOLOGY | ENGINEERING | MANUFACTURING | CONSTRUCTION

COMPARISON IN GRADATION

IS Sieve Size (mm)	RIVER SAND % Passing	PGBS % Passing	% Passing for single sized aggregates of Normal Sand (IS 383 - 2016) - Zone II
10	100	100	100
4.75	100	100	90 to 100
2.36	99.7	99	75 to 100
1.18	89	88	55 to 90
600	60.9	48	35 to 59
300	17.7	15	08 to 30
150	3.1	5	0 to 10
Remarks	**Zone II**	**Zone II**	

Ref:

"Evaluation of Processed Granulated Iron Slag Aggregate as per IS 383:2016" by SMR Prasad, JSW Steel, Karnataka

COMPARISON IN TECHNICAL SPECIFICATIONS

Properties	River Sand	PGBS	Remarks
Gradation	Cannot be controlled	**Can be controlled**	*Reduction in Voids and Higher strength*
Grading Zone (IS 383)	Mostly confirms Zone I & Zone II	**IS 383 - Zone II**	*Zone II ideal for Concrete*
Particle passing 75micron	Up to 3% (IS:383-2016)	**Up to 10% (IS:383-2016)**	*Up to 3% for uncrushed sand and Up to 10% for Manufactured sand (As per IS 383:2016)*
Clay and Organic impurities	Likely to be present (retard the setting & compressive strength)	**Absent**	*Alters Concrete Quality*
Bulk Density, kg/m3	1300 - 1600	**1300-1500**	
Specific Gravity	2.3 - 2.8	**2.4-2.7**	*May vary accordingly*
Water Absorption, %	1.5-3%	**<3**	*Limit 2%*

COMPARISON IN ORGANIC IMPURITIES

DESCRIPTION	RIVER SAND	PGBS	Remarks
Marine Products	2 - 4 %	Nil	Presence will alter the concrete quality
Oversized Materials	6 - 10 %	Nil	
Clay & Silt	5 - 20 %	Nil	

COMPARISON IN COMPRESSIVE STRENGTH

Fine Aggregates used	7th day Strength (N/mm²)	28th day Strength (N/mm²)
For M40, 100% River Sand	38-42	48-52
For M40, 100% PGBS	**42.9**	**53.3**
50% PGBS + 50% NS	39	52
50% PGBS + 50% M - Sand	40.8	52.3

Ref:
"Converting Granulated Blast Furnace Slag into Fine Aggregate" by D. Satish Kumar, JSW Steel Ltd, Karnataka

DESCRIPTION	RIVER SAND	PGBS	REMARKS
Environmental Impact	Yes	**Environmental friendly**	
Strength	As designed	**Higher than River sand (100% replacement)**	
Availability	Not easily available	**Readily Available**	
Economy	Higher price	**Lesser than River sand**	
Workability & its retention	Good & Good retention	**Less & Less retention**	*Control of fines & apply water absorption correction, use of plasticizers*
Pump able Concrete	Easily pump able with minimum wear/tear	**Moderate**	

CONCLUSION

CONCLUSION

Manufactured Sand is most preferred over River sand in terms of strength, minimized environmental impacts, unaltered quality of concrete due to unavailability of organic impurities, economical, etc.

However, M Sand is temporary solution to the replacement of river sand, as M sand is manufactured by crushing stones (natural resources). Hence it's high time to shift to non-natural aggregates without affecting the environment. Some of the feasible and economical solutions that have emerged in recent years are to reuse the industrial process wastes through recycling or reprocessing.

Processed Granulated Blast Furnace Slag is better alternative to River sand & M sand in terms of strength, usage of dumped industrial waste materials, ready availability, etc. It's economical than River sand, however transportation charges play a vital role.

Thank You

Qualities of Good Crushed Sand

-Dr.Aswath M U
Professor and Head
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The popularly known M-Sand is termed as Crushed Sand as per IS: 383-2016

The latest Indian Standard **IS: 383-2016**; ***"COARSE AND FINE AGGREGATES FOR CONCRETE- Specification (Third Revision)"*** covers the requirements for aggregates, crushed or uncrushed, derived from natural sources, such as river terraces and riverbeds, glacial deposits, rocks, boulders and gravels, ***and manufactured aggregates produced from other than natural sources,*** for use in the production of concrete for normal structural purposes including mass concrete works.

"As per the latest Indian standard IS: 383-2016, the popularly known M-Sand is termed as Crushed Sand. There are two types of them namely Crushed Stone Sand produced from crushing hard stone and Crushed Gravel Sand produced from crushing natural gravel"

The ***Crushed Sand*** produced by proper machines can be a better substitute to river sand. The sand must be of proper gradation (it should have particles from 150 microns to 4.75 mm in proper proportion). When fine particles are in proper proportion, the sand will have fewer voids. The cement quantity required will be less. Such sand will be more economical. Demand for ***Crushed Sand*** (fine aggregates) for making concrete is increasing day by day as river sand cannot meet the rising demand of construction sector. Natural river sand takes millions of years to form.

Fine aggregate maufactured from oter than natural sources, by processin materials, using thermal or other processes such as separation, washing, crushing and scrubbing are called manufactured fine agrgates(Manufactured Sand). Examples of manufactured sand are; Iron slag aggrgate, steel slag agregate,copper slag aggrgate, Construction and Demolition (C&D) waste etc.

Fine aggrgates produced by blending natural sand and crushed stone sand or crushed gravel sand in suitable proportions is called ***Mixed sand.***

General Requirements of *Crushed Sand*

1. All the sand particles should have higher crushing strength.
2. The surface texture of the particles should be smooth.
3. The edges of the particles should be grounded.
4. For crushed stone sands, the permissible limit on 150 µm IS sieve is increased to 20%.
5. There should not be any organic impurities

CRUSHED SAND

Crushed stone sand is produced by crushing hard stone or natural gravel. **CRUSHED SAND** is produced by rock-on-rock or rock-on-metal Vertical Shaft Impactor (VSI) 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 Crushed Stone Sand all the processes mentioned above can be done at manufacturing plant itself and controls are much better in producing quality fine aggregates.

Fine aggregates (**Crushed Sand**) proposed to be used shall be produced from a Vertical Shaft Impact (VSI) crushers and shall conform to the requirements of Zone-II (in most of the cases) as per IS 383-2016. Special efforts on the part of **Crushed Sand** manufacturers (such as washing of sand by water or dry washing by air) are required to restrict particles finer than 75 µm. **Crushed Sand** can also be used for making masonry mortar and shall conform to the requirements of IS 2116-1980 (Reaffirmed 1998) - "Specification of sand for Masonry mortars".

CRUSHED SAND QUALITY

Aggregates strongly influence concrete's freshly mixed and hardened properties, mixture proportions, and economy. Consequently, selection of aggregates is an important process. Although some variation in aggregate properties is expected, characteristics that are considered include:

- grading
- durability
- particle shape and surface texture
- abrasion and skid resistance
- unit weights and voids
- absorption and surface moisture

Crushed Sand should adhere to the highest standards and must undergo the following quality tests:

1. **Sieve analysis**
2. **Optical Microscopic Study to check the particle shape**
3. **Workability (slump test by slump cone method)**
4. **Cube test for compressive strength**
5. **Tests for Silt and clay**

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.
Limits of Deleterious Materials: The maximum quantity of deleterious materials shall not exceed the limits specified in Table 2 of IS 383:2016. 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 30 percent for concrete for wearing surfaces, such as runways, roads and pavements.30 percent for aggregate used for concrete other than for wearing surfaces.
Other parameters to be checked for quality are: **Aggregates Impact Value, Aggregate Abrasion Value and Soundness of Aggregate.**

SIZE AND GRADING OF AGGREGATES:

Grading refers to the determination of the particle-size distribution for aggregate. Grading limits and maximum aggregate size are specified because these properties affect the amount of aggregate used as well as cement and water requirements, workability, pumpability, and durability of concrete. In general, if the water-cement ratio is chosen correctly, a wide range in grading can be used without a major effect on strength.
For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete. The grading of fine aggregates, when determined as described in IS: 2386 (Part I) shall be within the limits given in Table 9 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 for a particular sieve size,(subject to a cumulative amount of 10 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.

SIGNIFICANCE OF GRADING: 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.

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).

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 in case of aggregates from natural sources;

c) Physical characteristics in case of aggregates from natural sources;

d) In case of manufactured aggregates, the brief manufacturing process, source of parent material and special characteristics having bearing on concrete properties, such as presence of adhered coating in case of recycled concrete aggregate, to the extent possible;

e) Presence of reactive minerals;

f) Service history, if any and in particular, in case of manufactured aggregates, the name of projects where used and the performance including in recently completed projects and;

g) In case of manufactured aggregates, special precautions, if any to be observed during concrete production.

Subject to prior agreement, the supplier shall furnish such of the following additional information, when required by the purchaser:

h) Specific gravity,

i) Bulk density,

j) Moisture content,

k) Absorption value,

l) Aggregate crushing value or aggregate impact value,

m) Abrasion value,

n) Flakiness-index,

o) Elongation-index,

p) Presence of deleterious materials,

q) Potential reactivity of aggregate, and

r) Soundness of aggregate,

Acknowledgement: *The content of the paper is sourced from* IS: 383-2016, coarse and fine aggregates for concrete -Specification, Bureau of Indian Standards, New Delhi for the purpose of knowledge dissemination only

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READY MIXED CONCRETE USING ALTERNATIVE FINE AGGREGATES and Quality Certification for Manufacturing

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

As on date the following two companies are approved as certification bodies.

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, Adheri 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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READY MIXED CONCRETE PLANT CERTIFICATION SCHEME (RMCPCS)

Ready Mixed Concrete Plant Certification Scheme (RMCPSC) is an independent, third party voluntary certification system designed to assure quality in operations and processes of RMC Plants. The **Quality Council of India (QCI),** India's apex quality facilitation body, set up by the Central Govt. is implementing the scheme. RMCPCS is developed by three high-powered QCI Committees with the participation from a large number of stakeholders (see box) from the government, semi-government and private sectors.

The scheme is a robust mechanism that ensures that any RMC unit that applies for a certificate has actually internalised best practices in their plant in accordance with the QCI-Building Materials and Technology Promotion Council **Criteria for Production Control of Ready Mixed Concrete** which is specified in the Scheme. The important aspects that are assessed during audit assessment include plant and equipment, concrete mix design, control on quality of concrete ingredients, control and maintenance of process, production and testing facilities and adequate emphasise on competence of key personnel manning the processes.

An RMC unit may apply to showcase and benchmark itself with quality certifications for any of the two options available with the RMC Plants Certification Scheme, one being **'RMC Capability Certification'** and other being **'RMC 9000+ Capability Certification'**, the latter ensuring compliance to the requirements of ISO 9001 also in addition to the QCI-BMTPC Criteria.

Multi Stakeholder Committees

- Central Government Ministries e.g. Ministry of Housing & Urban Poverty Allevation, Ministry of Road Transport and Highways, MES etc.
- Key Specifier: Central Public Works Department (CPWD)
- Central PSUs e.g. National Highway Authority of India, Airport Authority of India. RITES
- User bodies e.g. Builders Association of India, Construction federation of India. Professional bodies e.g. Indian Concrete Institute (ICI), Association of Consulting Civil Engineers (ACCE), CREDAI.
- Manufacturers e.g. Ready Mixed Concrete Manufacturers' Association (RMCMA), Cement Manufacturers· Association, (CMA) Certifying bodies e.g. Bureau Veritas Certification (I) Pvt Ltd, ICMQ India Pvt Ltd.

RMC Capability Certification

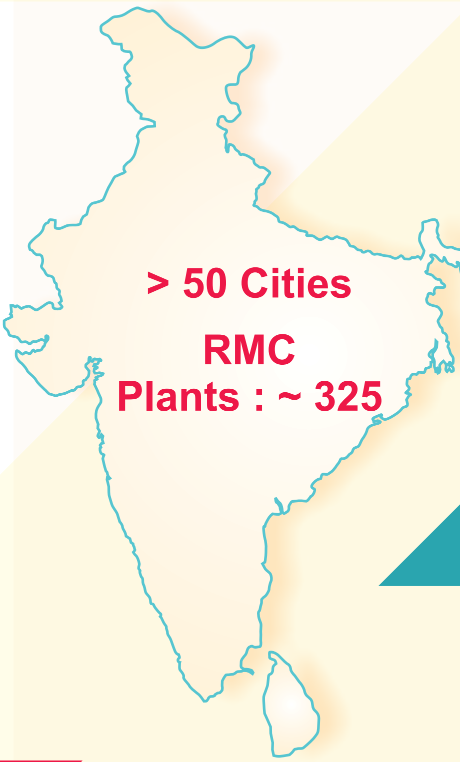
RMC 9000+ Capability Certification

RMC Plants under this QCI Scheme are certified by NABCB accredited Certification Bodies primarily complying with the requirements specified in the international standards, ISO/IEC 17065 and ISO/IEC 17021, as applicable, and the additional requirements prescribed by QCI.

Current Status

Till August 2017, around 325 RMC facilities in 50 cities have been either certified or under certification under RMCPCS.

RMCPCS has received the stamp of approval from a number of government bodies, host of architects and consultants and construction majors.



QCI Footprint

Key Benefits of QCI Scheme

For Owners and 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.

Approving Organizations

Government / Govt Agencies

- Govt of Puducherry
- Municipal Corporation of Greater Mumbai
- City & Industrial Development Corporation of Maharashtra Limited (CIDCO)
- Karnataka PWD
- Maharashtra PWD Handbook
- Nagpur Metro Rail Corporation Limited (NMRCL)
- Telangana State Industrial Infrastructure Corporation

Approving Organizations

Construction majors:

- L&T, Shapoorji Pallonji

Consultants / Architects

• A N Prakash Construction • A. K. Consultant • A S A Consultants • AKR Associates • Anand Tower • Buro Engineers (i) Pvt. Ltd. • Consultants Consortium • Continental Designers Dhrumataru Consultants • Design Tree • Design Courtyard • E P M C R Pvt. Ltd. • Er Nagesh Consultant/Architects • Gautam & Gautam Associates • Innotech Engineering Consult Pvt. Ltd. • K C Contech • Mysore • Matrix Consultant • N K Consultants • Narsimhan Associates • Potential Project Managers Pvt. Ltd. • Secunderabad • Sterling engineering Consultancy • STUP Consultants Pvt. Ltd. Suparna Associates • TRC Engineering (I) Pvt. Ltd. Yasha's Consultants • Tandon Consultants Pvt. Ltd.

Quality Council of India
Creating an Ecosystem for Quality

For further information contact
Quality Council of India (QCI)
2nd Floor, Institution of Engineers Building
Bahadur Shah Zafar Marg, New Delhi - 110 002 India
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RMCMA

" RMCMA supports RMCPSC"

2

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

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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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Recycled Aggregates in Concrete

By

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1.0 INTRODUCTION

Rapid modernisation and reconstruction of bridges, roads and industrial structures leads the concrete industry to draw enormous amount of natural resources and dispose large quantities of construction and demolition wastes in land fills. Considerably large volume of debris and rubble accumulates at demolition site, which is a serious threat to environment. Apart from reconstruction, debris results from natural calamities and the ravages of wars. The depletion in the supply of the quality aggregates has lead to the use of recycled aggregates. This will be advantageous economically and in long run, prove to be sustainable. Demolished wastes with partial substitution of natural aggregates by recycled aggregates originating from concrete provided a solution for the 200 million tons per year construction waste generated in European Union recently. In India, very few attempts have been made to use recycled aggregates on a large scale.

Demand for concrete for construction is on the increase, and at the same time, there is a shortage of natural aggregates in many urban areas. This has created a real and urgent need to consider using less satisfactory materials, which are of borderline quality. In the process of producing coarse aggregate from waste concrete, about 25% by weight of fine materials passing 5mm sieve size are generated. Borderline aggregates are those having deficiencies which do not make them clearly unacceptable but which leave some uncertainly about the extent of adverse effects on either strength or other engineering properties of concrete.

1.1 CONSERVATION

Conservation of natural resources and preservation of environment is the essence of any development. Rapid growth in population and urbanization are pushing the growth in construction, especially in the developing countries and old buildings are being demolished to be replaced with new ones. One of the problems arising from continuous technological and industrial development is the disposal of waste materials. It may be pointed out that Asia alone produces about 760 million tonnes of construction waste every year. Following this process indiscriminately leads to two basic problems. On one hand there is an urgent need to fruitfully use the construction debris, which is often simply thrown away or used as a filling material without considering the ensuing environmental problems. On the other hand, the industry is faced with the non-availability of good quality aggregates within reasonable distances and deforestation from thoughtless mining for aggregates from quarries. Infact, the problem with natural sand is even more serious and there is an urgent need to consider available options.

Some of the more than 5 billion tons of post consumer wastes and industrial by products generated annually in US are readily recyclable. Within the concrete industry, the most successful examples have been using coal fly ash to make high quality, durable concrete and recycling old, demolished concrete as aggregate for new concrete. The materials include

- Foundry sand and cupola slag from metal casting industries.
- Post consumer glass
- Wood ash from pulp mills, saw mills and wood product manufacturing industries
- Sludge from primary clarifiers at pulp and paper mills
- De-inking solids from paper recycling companies.

The above listed by products have been successfully used in concrete.

Cupola slag has also been used as coarse aggregate in concrete. The bulk density of cupola slag is 1280 kg/m^3 which is between that of normal weight aggregate (1600 kg/m^3) and structural light weight aggregate (1120 kg/m^3).The absorption for cupola slag is lower than that for the structural light weight aggregate.

1.2 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 common place 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 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 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.

1.3 INDIAN SCENARIO

In India, the waste from construction industry is estimated to be about 12 to 14.7 million tonnes per annum. The Indian construction industry is highly employment intensive and accounts for approximately 50% of the capital outlay in successive 5 year plans of the country. The projected investment in this industrial sector continues to show a growing trend. Rapid construction activity and growing demand for houses has led to the short fall of traditional building materials. Rapid industrialization has led to the generation of large quantities of wastes, which poses major problem of disposal. Disposal and utilization of industrial wastes is one of the major problems in India. Factors such as environment, economy, shortage of land for disposal and the shortage of good quality of raw materials for construction make it imperative that wastes should be suitably recycled.

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/m^2

And 40 –50kg/m^2 respectively. The highest contribution to waste generation is from demolition of buildings which yields 500 and 300 kg/m^2 of waste, for pucca and semi-pucca buildings respectively.

Waste constituents in million tonnes/annum in India:

Constituent	Quality generated in million tonnes/annum range
Soil, sand and gravel	4.20 – 5.14
Bricks and masonry	3.60 – 4.40
Concrete	2.40 – 3.67
Metals	0.60 – 0.73
Bitumen	0.25 – 0.30
Wood	0.25 – 0.30
Others	0.10 – 0.15

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2.0 RECYCLING

Recycling is defined as converting waste into reusable material. It is a process in which the materials are reprocessed and manufactured into same or similar products. Reuse is defined as using again i.e., second or further use of same material. When a material is used again without any treatment it is called as reuse in other words keep using the old one.

2.1 WHY RECYCLE AND REUSE

There is a difference between reusing an aggregate and recycling it. Reusing an aggregate usually implies taking a standard aggregate out of its use and putting it back again in a similar application. This can, in most cases, be done without much more extra work than cleaning and verifying its properties with standard aggregate test methods. Recycling aggregates is a different matter. Per definition, it can be a natural aggregate used in a road construction and then taken out to the use as a concrete aggregate. This is a simple scenario that does not need any special attention compared to freshly extracted aggregates.

Concrete is a manufactured product essentially consisting of cement, aggregates, water, admixture and additives. Among these, aggregates, the inert granular materials such as sand, crushed stone or gravel forms the major part. Traditionally aggregates have been readily available at economic prices and of qualities to suit all purposes. However in recent years the wisdom of concrete industry's continued wholesale extraction and use of aggregates from natural resources has been questioned at an international level. This is mainly because of the depletion of quality primary aggregates in some part of the world and greater awareness of environmental protection. In light of this, the availability of natural resources to future generation has also been realized. Recently published reports states that immediate and simultaneous steps are required following total devastation with the Gujarat earthquake of January 26th 2001. It has been estimated that over 4 Lakh dwelling units may have collapsed, creating large amount of debris. Removal of such debris and reusing it in value added applications have been identified as one of the key priorities. Thus construction and demolition waste has become a global concern that requires sustainable solution.

On the other hand, it is now widely acknowledged that there is a significant potential for reclaiming and recycling construction and demolished debris for the use in value added applications to maximize economic and environmental benefits. As a direct result of this construction and demolition waste is increasingly being seen as a valuable source of construction materials such as aggregate for new concrete production.

2.2 IMPORTANCE OF RECYCLING

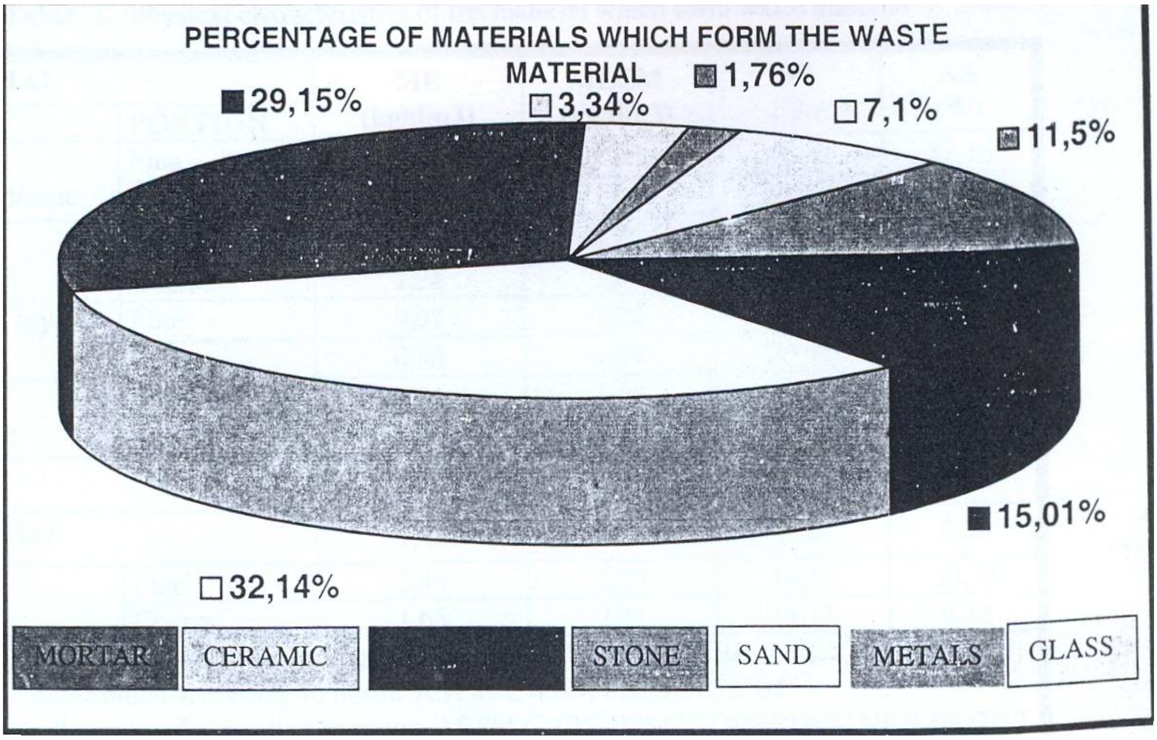
The recycling and reuse of rubble from buildings including concrete, bricks and tiles should be dramatically increased not only because this will conserve and extend natural resources but also because landfill sites in urban areas are very limited. This requires the status of the recycled material to be elevated through research, development and generation of performance data for the material as compared to virgin materials.

While most of the C&D waste is used in land filling of low lying areas, research in different countries has suggested the possibility of reusing hard inert materials like demolished concrete. A formal framework for use of recycled construction waste is in different stages of development in different parts of the world, but is virtually non-existing in India. The construction boom in India coupled with limited supply of natural aggregates and the emphasis on infrastructure development has brought the recycling option to the forefront.

Recycling of the construction wastes is considered as the need of the hour. Research in different countries has suggested the possibility of reusing the hard inert materials in the construction wastes. Broken concrete and bricks mostly from buildings can be used to give “recycled aggregate concrete (RAC)” and similarly broken pavement can be used to build “reclaimed asphalt pavement (RAP)”. The rate of use of recycled aggregates is influenced by availability, engineering performance and by financial incentives that encourage the use of RAP and RAC.

2.3 CHARACTERISTICS OF THE COMPONENTS OF WASTE MATERIALS:

- **Recycling waste materials:** are the ones which can be incorporated in the physical edification due to their petrous origin such as minerals, rocks, glass and metal either in their simple or compound form.
- **Non-recycling waste materials:** are the ones which cannot be incorporated in the physical body of the building due to their non-petrous origin such as wood, vegetation, plant remains, paper and fabrics.



2.4 <u>RECYCLING AS AN OPTION</u>

The 8th five-year plan envisages a shortage of aggregates in housing construction sector. Further for achieving the target for road development upto 2010,an estimated 750 million m^3 of coarse aggregate as sub-base material will be required. Recycled aggregate can fill part of this demand supply gap. From the different studies regarding the use of recycled concrete as raw material for 'new' concrete, it has also been reported that the properties of concrete prepared with RCA would vary widely depending upon the source of recycled aggregate, age of concrete at the time of demolition etc. The recycled aggregate is known to have higher water absorption due to the residual mortar attached to it. It has also been found that concrete made with recycled aggregate shows higher levels of shrinkage and creep when compared to that of normal concrete. It is also observed that the use of recycled aggregates leads to a reduction in the compressive strength of the concrete and the replacement ratio strongly affects other properties of new concrete.

In view of significant role of recycled construction material and technology in the development of urban infrastructure, technology, information, forecasting and assessment council had commissioned a techno-market survey on "Utilization of waste from Construction Industry". The focus of their study was to assess the present knowledge of the Indian Construction Industry on the possibility of recycling of wastes. The survey was targeted towards the housing/building sector and road construction segment. According to findings of survey, the most dominant reason for not adopting recycling of waste from construction industry is "Not aware of the recycling techniques". While 70% of the respondents have cited this as one of the reasons, 30% of the respondents have indicated that they are not aware of recycling possibilities. The response of industries which can use the recycled product indicates that presently the specifications do not provide for use of recycled product in the construction activity.67% of the respondents from user industry have indicated non-availability of recycled product as one of reasons for not using it.

3.0 <u>CLASSIFICATION OF RECYCLED AGGREGATES</u>

RILEM has released a recommendation (RILEM, 1994) which gives away of classifying the recycled aggregates into three different types. They are

Type 1 ------ Aggregates, which are implicitly understood to originate primarily from masonry rubble

Type 2 ------- Aggregates, which are implicitly understood to originate primarily from Concrete rubble

Type 3 ------- Aggregates, which are implicitly understood to consist of a blend of recycled aggregates and natural aggregates

3.1 HURDLES FOR THE USE OF RECYCLED AGGREGATES

Despite a large body of laboratory research data showing that recycled aggregates can give excellent performance in concrete, practical use in the concrete industry has been restricted by questions of specification, risk, availability and cost.

Specification and Risk:

In a recent study on the relationship between specifications and the use of recycled materials and other wastes as aggregates, it was concluded that British Standards in themselves (and in particular, BS 5328 for concrete) did not prevent the use of recycled aggregates in concrete. The main reason for exclusion of such material is the wording of contract specifications, which in addition demand compliance with BS 882 (Natural aggregates for concrete). Only BS 1047 (Blast furnace slag aggregate) or sometimes BS 3797 (light weight aggregate) are allowed as alternatives. To use any other type of aggregate, evidence of suitability for purpose (as required in BS 5328) is not in itself sufficient for specifiers. Whether or not the substitution of recycled aggregates for natural aggregates in concrete increases the risk of failure, modifying the specifications to allow little used non-BS materials will tend to place all of risks pertaining to its use on the specifier. This will result in unacceptable extra costs which will probably be difficult to quantify.

The only practical course until such use of recycled aggregates becomes more common is for the client to take in this part of the risk. The client may be prepared to do this either to save costs or more likely to gain “green” credentials. It is possible, however that the client may be prevented by fund holders in their own specifications from taking extra risks or using recycled aggregates.

Availability:

Because of the problems outlined above, there is no demand for high quality processing of recycled aggregates in UK. This means that under most circumstances, the correct grading and quality of material has to be pre-ordered whereas suitable natural materials are available "off the shelf". This is a "catch 22" situation – there are no accepted standards or specifications because no one uses the material since it is not ready prepared and no one will prepare the material as there are no standards.

Cost:

The need for trial mixes and quality control has cost applications. Obviously, as a market develops, such costs will be reduced but are likely to remain higher than for natural aggregates. Costs will also be incurred for the higher cement contents often required by recycled aggregates. Such costs may eventually be offset by the increasing cost for landfill.

3.2 THE RILEM RECOMMENDATION

The specification followed for the recycled aggregate was RCAC type 2 (crushed concrete) in the RILEM Recommendation (2). This recommendation is currently being considered by an ad hoc group of CEN/TC 154 (aggregates) for incorporation within European Standards. According to RILEM Recommendation, low-level replacements (upto 20%) have little practical effect on the properties of concrete. RCAC type 1 material (mainly crushed brick) is recommended only for lower strength and for less aggressive conditions.

SPECIFIC RECOMMENDATIONS FOR THE USE OF RECYCLED AGGREGATES:

Recycling of Construction & Demolition Waste				
Country	**Annual Production (kT)**	**% age used**	**Application of the %age used**	
Belgium	7000 (1990)	87%	Aggregate for concrete: 17%	Roads: 70%
France	24000 (1990)	15%	Aggregate for concrete: 1.5%	Roads: 8.2%
				Embankments & fill: 5.3%
Great Britain	30000 (1999)	45%	Aggregate for	Roads: 9%

			concrete: 2%	Embankments & fill: 34%
European Union	180000 (1999)	28%	Aggregate for concrete: 2.2%	Roads: 9.5%
				Embankments & fill: 16.3%
Spain	38500 (2003)	10%	Subbase for roads: 3% As soil base: 3.5%; fill:3.5%	

SCOPE:

The draft regulation will establish limitations on the use of recycled aggregates for structural concrete along general lines set out below:

- Use of recycled aggregate will be restricted to mass concrete and reinforced concrete and its use for pre stressed concrete will be prohibited.
- Only the use of aggregate obtained from the recycling of conventional concrete will be recommended, excluding special types of concrete such as light weight concrete, fibre reinforced concrete and concrete made using aluminous cement.
- As a general rule, provision will be made for use of the larger grade of recycled aggregate (minimum size greater than 4mm) in place of a limited amount of natural aggregate, set at 20% substitution by weight. One issue that will have to be decided is whether to allow substitution only for certain granulometric grades or to allow substitution across the full size range of large aggregate.
- The use of recycled aggregate for concrete that will be exposed to aggressive environments will be allowed only were special precautions are taken to be specified for each case including for eg., recommendations for use of recycled aggregate from a single verified source only, completion of supplementary testing, higher cement content or a lower water to cement ratio in mixing and so on.

The restriction of the percentage of recycled aggregate recommended for use and the specifications required in respect of its quality and uniformity will make it possible to ensure that the properties of recycled concrete do not differ significantly from those of conventional concrete.

3.3 <u>STANDARDS AVAILABLE FOR AGGREGATE</u>

The aggregate used for the recycled concrete must meet the standards set out in the Structural Concrete Instruction (EHE) as shown below.

Due to the lower quality of the recycled aggregate and its heterogeneous nature some of these specifications might not be met in most cases.

Properties	**Testing method**	**EHE specifications**
Fines content	UNE – EN 933-2:96	<= 1
Shape coefficient	UNE 7238:71	>= 0.2
Absorption (%)	UNE 83134:98	<= 5
Los Angles coefficient (%)	UNE – EN 1097-2:99	<= 40
Cl^- soluble in water (%)	UNE – EN 1744-1:99	<= 0.05
Sulphates soluble in acid SO_3 (%)	UNE – EN 1744-1:99	<= 0.8
Total Sulphur compounds SO_3 (%)		<= 1
Light weight particles (%)	UNE – EN 1744-1	<= 1
Clay lumps	UNE 7133:58	<= 0.25
Soft particles	UNE 7134:58	<= 5
Weight loss with magnesium sulphates (%)	UNE – EN 1367 – 2:99	<= 18

The test methods set out in the above table are valid for recycled aggregates, although they should be applied with certain precautions in respect of content of light particles, resistance to freezing, lumps of clay and soft particles.

FINES CONTENT:

	Fines content (< 0.063 mm) (%)
Rilem	<= 2
Belgium	<3
Hong Kong	<4
Germany	<4
Australia	<6
England (BS EN 206-1)	<5

4.0 <u>RECYCLED COARSE AGGREGATE</u>

4.1 INTRODUCTION

Recycled aggregate concrete utilizes demolition material from concrete and burnt clay brick masonry construction as aggregate. Reuse of demolition waste avoids the problem of waste disposals and it’s also helpful in reducing the gap between the demand and supply of crushed granite fresh aggregate. While the amount of demolition waste materials generated in India has not yet been quantified properly, it is thought that presently the yearly rate of demolition of buildings and other structures in the major cities has reached 1-2%.

This is mainly due to the following reasons:-

- Demolition of structures which have become obsolete either in serving the basic functions or due to structural deterioration.
- Demolition of structures for better economic gains.
- Waste construction materials formed due to natural disasters like earthquake, cyclone and flood.
- War inflicted damages.

Recycled aggregate concrete can utilize demolition material from concrete and masonry constructions. Though several studies have been made on the reuse of concrete waste only limited studies have been made with respect to use of demolished brick masonry as aggregate. The three types of demolition wastes are:

- Concrete
- Wire cut brick masonry
- Table moulded brick masonry

Different forms of coarse aggregate includes:

- Relatively clean coarse aggregate with very small amounts of adhering mortar on one or more spots
- Coarse aggregate with a thin film or old paste covering most of the aggregate surface
- Coarse aggregate with a relatively thick layer of old mortar (2 to 3 mm)
- Coarse aggregate with a lump of mortar on one side
- Particles made entirely of old mortar
- Contaminants such as brick pieces. Very few of these particles are present and may only amount to 1 or 2%.

4.2 TESTS ON AGGREGATE

The basic characteristics of the materials proposed to be used are determined. In order to have a basis for comparison, the properties of fresh granite aggregate were determined. Three types of recycled coarse aggregates were prepared from old concrete cubes of unknown strength (original strength), masonry with wire cut bricks and masonry with table moulded bricks. Using a 1000 kN compression testing machine they were crushed, followed by use of hammer. The crushed products were screened through 25 mm sieve and the aggregates retained on IS sieve no.480 were used for making recycled aggregate concrete. The physical and mechanical properties of these aggregates were determined as per IS:2386 and compared with those of fresh granite aggregate. The following table consists of the properties.

4.3 PROPERTIES OF RECYCLED COARSE AGGREGATE

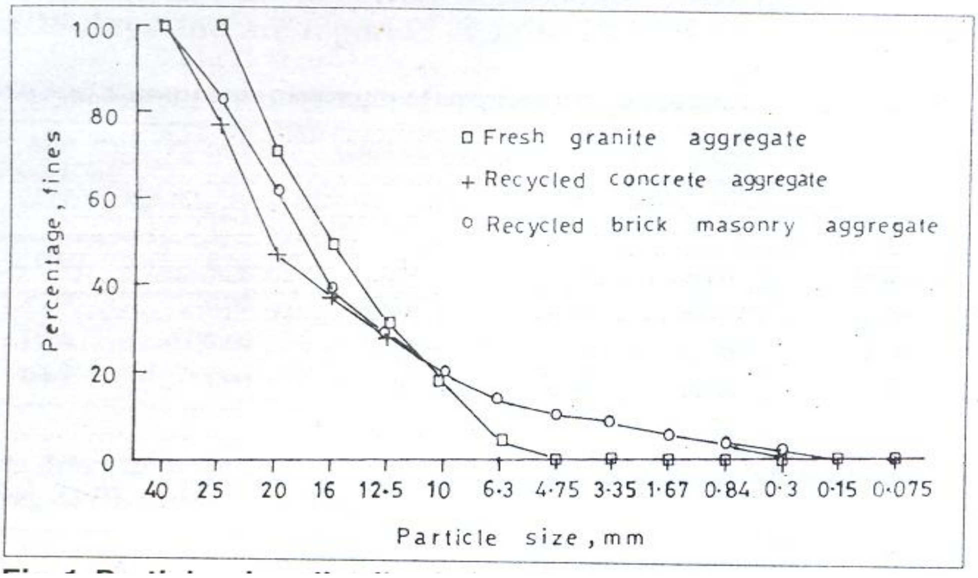
Physical and Mechanical properties of Coarse Aggregate from Demolition waste:

		Type of Aggregate used			
Property of aggregate		Fresh Granite Aggregate	Demolished Concrete Aggregate	Demolished Masonry Aggregate (with wire cut brick)	Demolished Masonry Aggregate (with table mounted)
Specific Gravity		2.62	2.38	1.78	1.64
Water Absorption	%	3.5	8.3	9.67	14.2
Bulk Density (kg/m^3)	Rodded	1430	1584	1193	1000
	loose	1310	1194	980	910
Voids	Rodded %	45.4	33.44	33.0	39.0
	loose %	50.0	49.83	46.0	44.5
Flakiness index	%	33.0	30.0	43.0	46.0
Elongation index	%	26.0	28.0	40.0	46.0
Crushing value	%	29.5	38.0	72.0	85.0
Impact value	%	16.0	58.0	64.0	66.0

- Source: K. Ramamurthy & K.S.Gumaste (Indian concrete Journal – Jan 1998)

4.4 RESULTS AND DISCUSSION

- Particle size Distribution



Particle size distribution of fresh granite and recycled aggregates

The above figure shows the result of sieve analysis carried out as per IS 2386, for different types of crushed demolition aggregates. It is seen that the coarse aggregate of concrete as well as brick rubble are well graded, that is the concrete and brick masonry are reduced to various sizes during the process of crushing. The amount of fine aggregate in demolished concrete and brick masonry were in the range of 5-10 % and 10-15% respectively.

- Specific gravity and water absorption

The specific gravity (saturated surface dry condition) of demolished concrete aggregate is lower than that of natural aggregate. Since the aggregates from crushed concrete consist of granite aggregate with old mortar adhering to it, the water absorption is relatively higher than that of the fresh granite aggregates. The specific gravity of both types of recycled masonry aggregates (using table moulded and wire cut bricks) have been found to be lower than that of recycled concrete aggregate. Due to higher porosity of the country bricks, the water absorption is higher than that of the table moulded bricks. In general, as the water absorption characteristics of recycled aggregates are higher, it is advisable to pre-soak the aggregates before using the same for concrete making.

- Bulk density and Voids

It can be observed from the above table that though the rodded bulk density of recycled concrete aggregate is higher than that of fresh granite aggregate, its loose bulk density is lower than that of the fresh one. The mortar adhering to recycled concrete aggregate increases the size of aggregate and has a better interlocking which in turn reduces the voids in rodded condition. The lower value of loose bulk density of recycled concrete aggregate may be attributed to its higher porosity than that of fresh granite aggregate.

The bulk density of both types of recycled brick masonry aggregates observed were lower than that of recycled concrete aggregate. As per ASTM C 330-1985, the upper limit for bulk density of lightweight coarse aggregate is 880 kg/m^3. As the bulk density

of both types of recycled brick masonry aggregates are higher than the above value, they do not fall under the category of light weight aggregate.

It may be noted that the aggregate from masonry with wire cut bricks had percentage voids almost similar to that of recycled concrete aggregate, while this value is higher for aggregate from masonry with table moulded bricks. This is because to the fact that table moulded brick aggregate has a tendency to crush and re-adjust during packing

- Elongation and Flakiness indices

The elongation and flakiness indices of recycled concrete aggregate were closer to that of fresh granite aggregate. Recycled brick masonry aggregates are observed to have relatively higher elongation and flakiness indices than those of crushed concrete aggregate.

- Crushing and impact values

The recycled concrete aggregate is relatively weaker than the fresh granite aggregate against mechanical actions. As per IS: 2386 (part 4), the crushing and impact values for concrete wearing surfaces should not exceed 30% and for other concrete works these values should not exceed 45% and 50% respectively. While the crushing value of recycled concrete aggregate satisfies crushing value specification for concreting works other than wearing surfaces, the impact value is higher. The crushing and impact values of recycled brick masonry aggregates are much higher than those of recycled concrete aggregate and also do not satisfy the specifications. Such a failure to meet the specifications need not be a constraint for using these aggregates in making low and medium strength concrete.

4.5 TESTS ON RECYCLED AGGREGATE CONCRETE

Ordinary Portland cement 43 grade and natural river sand passing IS sieve no.480 were used for production of parent specimen and recycled aggregate concretes. Crushed granite having a maximum size of 25 mm was used as coarse aggregate in the parent concrete. In order to study the relative strength characteristics of aggregates obtained from recycled concrete and masonry, four nominal mixes of concrete having proportions 1:1.5:3; 1:2:4; 1:3:5 and 1:4:7 were produced using fresh granite aggregate and the three types of recycled aggregates mentioned above.

In order to maintain uniform quality during concrete production, aggregates were pre-soaked in order to compensate the high water absorption of recycled concrete and brick masonry aggregates. The water requirement for each of the four nominal mixes have been decided based on a compacting factor of around 0.85. Properties of fresh concrete have been measured through compacting factor for original and recycled aggregate concrete. 32 cubes were cast for each of the four mix proportions using fresh granite aggregate, out of which 6 each were for 7 and 14-day strength tests and 20 cubes were for 28-day strength test. 18 cubes were cast for each of the four proportions with three recycled aggregates for carrying out compressive strength tests on 6 cubes at 7, 14 and 28-day for each mix.

4.6 RESULTS AND DISCUSSION

- Compressive Strength

The mean compressive strengths (of 6 cubes each) of 150 mm concrete cubes are cast using different aggregates. They include fresh granite, recycled concrete, Wire cut brick masonry and Table moulded brick masonry

The compressive strengths were determined at the age of 7, 14 and 28 days.

Mix proportions	Water/cement ratio	Compacting factor	Mean compressive strength, N/mm^2 at		
			7- day	14-day	28-day
1:1.5:3	0.50	0.87	33.14	43.13	49.80
1:2:4	0.52	0.83	22.80	32.20	41.50
1:3:5	0.60	0.83	15.00	25.40	32.70
1:4:7	1.00	0.85	14.40	18.20	22.00

Table 1:Compressive strength of concrete with fresh granite aggregate

Mix proportions	Water/cement ratio	Compacting factor	Mean compressive strength, N/mm^2 at		
			7- day	14-day	28-day
1:1.5:3	0.50	0.87	20.13	33.74	40.00
1:2:4	0.60	0.84	17.95	26.40	35.30
1:3:5	0.80	0.85	12.80	18.20	22.70
1:4:7	1.10	0.85	8.46	10.20	12.76

Table 2: Compressive strength of concrete with recycled concrete aggregate (from concrete of unknown strength)

Mix proportions	Water/cement ratio	Compacting factor	Mean compressive strength, N/mm^2 at		
			7- day	14-day	28-day
1:1.5:3	0.50	0.86	11.95	15.50	16.30
1:2:4	0.60	0.83	11.76	14.40	16.20
1:3:5	0.90	0.85	7.80	10.00	10.70
1:4:7	1.15	0.86	5.50	6.84	10.10

Table 3: Compressive strength of concrete with recycled brick masonry aggregate with wire cut bricks

Mix proportions	Water/cement ratio	Compacting factor	Mean compressive strength, N/mm^2 at		
			7- day	14-day	28-day
1:1.5:3	0.50	0.87	10.13	12.26	14.61
1:2:4	0.55	0.87	9.70	12.60	14.12
1:3:5	0.60	0.83	7.80	10.74	12.20
1:4:7	1.27	0.86	5.44	7.70	9.12

Table 4: Compressive strength of concrete with recycled brick masonry aggregate with table moulded bricks

The strength of recycled aggregate concrete with aggregate from concrete of unknown strength, is relatively lower than that of the concrete made with fresh granite aggregate. (table 1 and 2)

The strength reduction in richer mixes of concrete (1:1.5:3 and 1:2:4) has been observed to be between 15 and 20%, in case of leaner mixes (1:3:5 and 1:4:7) the reduction is between 30 and 42%. The reduction in strength may be due to two reasons:

- The relatively higher water requirement of recycled aggregate concrete (to maintain a uniform compacting factor) than that of corresponding mixes of concrete with fresh granite aggregate.
- The weaker bond between fresh mortar and the old mortar adhering to the recycled concrete aggregate.

In general, the compressive strength of concrete with recycled brick masonry aggregates (Tb 3 & 4) is considerably lower than that of the corresponding mix of concrete with recycled concrete aggregate (Tb 2). The variation in the compressive strength between the concretes with two types of recycled brick masonry aggregates is rather low. The compressive strength of recycled brick masonry aggregate concrete, even in case of a very lean mix of 1:4:7 is of the order of 9 to 10 N/mm^2, which may be considered equivalent to the compressive strength of commonly available good quality bricks suitable for low-rise, load bearing masonry construction. As the mixes 1:1.5:3 and 1:2:4 result in a compressive strength in the range of 15 N/mm^2 they can be used for RC work. The leaner mixes are suitable for PCC works and brick manufacture.

In the case of concrete with fresh granite and recycled concrete aggregate, the reduction in strength is gradual as mix becomes leaner (Tb 1 & 2), whereas this reduction is not pronounced in concrete with both types of recycled brick masonry aggregates (Tb 3 & 4). The reason may be due to higher crushing value of recycled brick masonry aggregates. Crushing of aggregates in concrete governs the failure of cubes thereby reducing the influence of mix proportion.

A comparison of rate of strength gain with age for each of the four mixes with fresh granite and different types of recycled aggregates show that the rate of strength gain is relatively steeper in cases of fresh granite and recycled concrete aggregate as compared to that of recycled brick masonry aggregates.

4.7 <u>CONCLUSIONS</u>

- Recycled aggregates possess relatively lower bulk density and higher water absorption as compared to that of fresh granite aggregates.this is mainly due to the porous mortar adhering to the recycled concrete aggregate and the relatively higher porosity of bricks.

- Though the impact value of recycled concrete aggregate and both impact and crushing values of two types of recycled brick masonry aggregates are exceeding the BIS specified limits, it has been shown through the range of compressive strengths obtained that recycled concrete of different mixes made with recycled aggregates obtained from demolished brick masonry can be used for manufacture of load bearing units and PCC works. The demolished concrete aggregates can be used for both PCC and RC construction
- The compressive strength of recycled aggregate concrete is relatively lower and the variation depends on the strength of original concrete from which the aggregates have been obtained. This reduction is mainly caused by the bond characteristics of recycled aggregate and the fresh mortar of the recycled concrete
- It is advisable to carry out trial castings with the recycled aggregate proposed to be used, in order to arrive at the water content and mix proportions to suit the workability levels and strength requirements respectively.

SALIENT CHARACTERISTICS OF RECYCLED AGGREGATE AND CONCRETE PRESENTED BY VARIOUS AUTHORS

Property of recycled aggregate and recycled aggregate concrete:

Author (year)	Properties of recycled aggregate				% reduction in strength of RAC compared to original concrete
	Density (kg/m^3)	Water Absorption (kg/m^3)	Crushing value (%)	Abrasion value (%)	
Malhotra (1976)	2500-2530	3.9 – 4.4 CA 7.9 – 9.6 FA	18	26	10 - 20
Buck (1976)	2590	2.3 – 4.5 CA	--	--	--
BCSJ (1978)	1970- 2140	3.6 – 8 CA 8.3 – 12 FA	22	36.5	14 - 32
Nixon (1978)	2430 CA	--	--	--	20.0
Hasaba (1981)	2430 CA	7 CA 11 FA	23.0 HSC 24.6 LSC	--	12.0
Weshe (1982)	--	7	--	--	10.0
Hansen (1983)	2490	8.7 – 3.7	6 - 12	41.4 HSC 22.4 LSC	22.0

Geradu (1985)	--	8	--	--	5.0
Ravindrarajah (1985)	2440- 2460	4.5 – 5.4	8 – 12	29	8 - 12

HSC – High Strength Concrete LSC – Low Strength Concrete

From the above table it can be noted that the percentage reduction in compressive strength of recycled aggregate concrete as compared to original concrete range between 5 to 32%.

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