9th EDITION

Concrete

PANORAMA & DEMINAR

CONCRETE PANORAMA & DEMINAR 2021™

ICI-BENC

Two-Day International Seminar Cum Deminar

LIVE PRODUCT DEMONSTRATION AND EXHIBITION ON

Alternative Materials and Innovative Technologies in Concrete Construction

16th - 17th March 2021

Venue: BMS College of Engineering, Bull Temple Road, Bengaluru - 560 019

Organised by

INDIAN CONCRETE INSTITUTE
BENGALURU CENTRE

In association with

Department of Civil Engineering
BMS College of Engineering
Bengaluru - 560 019




SEMINAR DOCUMENT

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Secretary, ICI, Bengaluru Centre

Dr. R Nagendra
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Preface

We are pleased to place this Seminar Document in your hands which is brought out to coincide the 9th Edition of the **Concrete Panorama and Deminar 2021** on the theme of **'Alternative Materials and Innovative Technologies in Concrete Construction'.** Deminar is a unique format of the Demonstration and Seminar on technologies and materials related to concrete construction initiated by the Bangalore centre of Indian Concrete Institute for the first-time way back in 2009. This is one of the flagship programs of ICI-BENC which is happening every year since then.

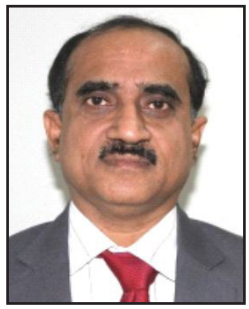
The technical committee has decided to bring out a Seminar Document on this occasion. It consists of collections of technical articles on the subject besides the details of the several Innovative products and technologies exhibited in the Deminar. As it also contains advertorials of the corporates participating in the event, it is intended to serve as a ready resource of their details.

We sincerely hope this Seminar Document makes a good reading to all the participants and carry sweet memories of the event back home.

We take this opportunity to thank all the individuals and organisations, who have supported us to bring together under one platform the various technologies and materials demonstration and exhibit to all the delegates.

M N Ramesh
Editor- in- Chief

Message by Chairman-Organising Committee



Indian Concrete Institute, Bengaluru Centre is presenting 9th edition of "Concrete Panorama & Deminar-2021" to disseminate knowledge on the subject of "ALTERNATIVE MATERIALS AND INNOVATIVE TECHNOLOGIES IN CONCRETE CONSTRUCTION". This annual event is being organized in association with Department of Civil Engineering, BMS College of Engineering, Bangalore.

Deminar is a unique feature of Concrete Panorama where in we offer an opportunity to manufacturers of innovative concrete materials and technologies to showcase usage of their products/technologies through real time demonstration which is beamed live in the auditorium. This helps the delegates to interact with the manufacturers while demonstration is going on. This kind of deminar is the only one in India which has been so popular amongst engineers to learn new technologies and new products.

This event adds another dimension of learning experience as it is being conducted at a reputed academic institution such as BMS College of Engineering, Bangalore whose support for the event is invaluable. I also take this opportunity to acknowledge the support from the construction industry in organizing event of such a magnitude year after year.

The organizing committee under the guidance from the panel of experienced advisors has put tireless efforts in making this event a success. On behalf of Indian Concrete Institute, Bengaluru Centre I wish all the participants a happy interaction and learning experience.

Dr. R. Nagendra
Chairman-Organising Committee
Deminar 2021

Message by President - ICI

I am so delighted to learn that ICI, Bengaluru centre is organizing the mega event on **"Alternative Materials and Innovative Technologies in Concrete Construction"** as a physical event after a very long time, given the pandemic era.

We live in the world of finite resources. Hence, it is extremely important to find alternative materials. One to conserve our limited natural resources, two to reduce Green House effect that is created by production of cement. Of late, materials like Fly-ash, GGBS, Metakaolin, Micro-silica, Ultra-fine cement, manufactured sand have found their way through as alternatives to the conventional materials. Concrete and structural steel have always been alternatives to each other.

Fly-ash bricks, hollow concrete blocks, reinforced masonry, dry cladding, dry wall are some of the recent developments. Imagine, if these alternative materials were not researched, civil engineering would have become rather difficult.

I appreciate the careful selection of themes and speakers, the Bengaluru centre has made.

My good wishes remain with enthusiastic team of Bengaluru.

Good luck to all!!

Er. Vinay Gupta
President,
Indian concrete Institute

Message by Vice President (South) - ICI

When it comes to ICI Bengaluru Centre whether it is webinar/virtual meeting/seminar/Deminar, I appreciate your challenging and terrific enthusiastic, ambitious motivating attitude. Further now, in such an extraordinary situation and you have come up with good ideas of organising the mega event as a Physical event on "Alternative Materials and Innovative Technologies in Concrete Construction". Thanks for being an exemplary Team, I feel honoured as I get associate myself with you creative people and keeping up with the good work.

On one side there is considerable development of new infrastructure in the country and on the other side we have substantial quantum of structures of either old vintage or within their service life, which are showing symptoms of structural distress. Hence considering the rapid infrastructure growth in India, it is necessary to use alternative Cementitious binders which are more environment friendly and durable.

Calcium sulfoaluminate-belite (CSAB) cements have shown a remarkable promise by offering significant reduction in carbon footprint, shrinkage cracking, sulphate attack compared to Portland cement thereby sustainability and durability of concrete is established.

Buildings are responsible for an enormous amount of global energy use and resource consumption and greenhouse gas emissions. Alternative aggregates such as iron slag aggregates, steel slag aggregates, recycled concrete, recycled aggregates and copper slag aggregates, GGBS, manufactured sand are identified as supplements to sand from natural resources.

I hope that in this Two-Day International seminar cum Deminar, the learned speakers will focus on various topics related to "Alternative Materials and Innovative Technologies in Concrete Construction" which are need of the hour. The Concrete Panorama and Deminar will be beneficial to the delegates from various discipline to take it forward for improvement in the construction industry and thereby resulting in the betterment of the society.

Best Wishes

Er S.SURESH
Vice President (South)
Indian Concrete Institute

Message by Secretary General - ICI

ICI is a platform for all segments of the people, associated with the concrete Industry that facilitates learning and sharing. ICI events knit the people together for sharing their ideas, views and thoughts earned from their experience.

Concrete Industry, like any other technology, is developing fast. With the invention of Innovative materials and sustainable processes, rapid developments in the industry necessitate dissemination of knowledge for the benefit of all the stakeholders in the industry, to achieve professional excellence.

Deminar is a novel event organized every year by the Bengaluru Centre. Industry people anxiously wait for this event every year to demonstrate their products. Bengaluru centre, with all its might, celebrate this event in a grand manner e

very year. It is a combined event demonstrating the theory. Let us look forward for this innovative annual event .

My hearty congratulations for the Organizers and the participants and I wish the program all success.

Er. R Radhakrishnan,
Secretary General.
Indian Concrete Institute

Message by Chairman, ICI - Bangalore Centre

Indian Concrete Institute Bangalore centre is one of the most active centres among 44 centres of Indian Concrete Institute on All India basis and has won 16 out of 28 best centre awards with continuous efforts and more focus on student chapters, conducting seminars, Workshops, Webinars, Concrete Fairs and technical lectures, Concrete day lectures and awards functions for disseminating knowledge for the benefit of concrete and construction professionals in line with the objective of the Institute.

The two day International Seminar ,Concrete Panorama and Deminar in its 9th Edition is on "Alternative Materials and Innovative Technologies in Concrete Construction" is an important event where presentations, demonstrations and Exhibition of new innovative alternative materials and new innovative technologies will be showcased which is more relevant in today scenario as there is constant need to preserve the natural resources and reduce the impact on environment as the demand for construction materials is constantly growing.

This event is one of the first physical program and mega event happening under ICI, Post COVID 19 and we are expecting greater participation from the Industry, ICI Members across India and student chapters and the event is happening at an Education Institute of high repute, BMSCE, Bengaluru.

All the efforts are being made by the organizing committee for the deliberations among researchers, Academia and Industry, Deminar, Product presentations and Exhibitions and I am sure that all the participants will have some value addition and learn from the best practices on use of Alternative materials and Innovative technologies in concrete constructions.

I thank all the advisors and organizing committee members and MC Members for their continuous support and guidance in making this event happen during these testing time and wish the program a grand success.

Best wishes

Dr. L. R. Manjunatha,
Honorary Chairman,
Bengaluru Centre

Message by Secretary, ICI - Bangalore Centre

Welcome to all the Civil Engineering Community!!!
Indian Concrete Institute, Bangalore Centre presents 9th Edition of Two Day International Seminar Cum Deminar & Live Product Demonstration & Exhibition on "Alternative Materials and Innovative Technologies in Concrete Construction".

Deminar is a Flagship Event much appreciated by all the construction Professionals. Concrete is a mysterious construction material and it keeps on evolving continuously presenting fresh challenges in construction industry. Hence meeting these construction issues and identifying the innovative technologies and smart material is the need of the hour.

Fast track construction being the order of the day the field and practicing engineers must not to lose focus on the Quality Aspects. Hence, it is being our constant effort to enhance the knowledge of all the professionals by organizing various technical activities and keep sharing and facilitating interactions with the industry experts round the year.

One such effort has been made to Accentuate on the importance of existing and upcoming practices and technologies for Budding Engineers, Research scholars, Students Community & Practicing Engineers of Construction industry in this event of Concrete Panorama & Deminar 2021.

Knowledge enhances by sharing and hence creating awareness (Demonstration and Seminar) only makes our "Construction Practices Better for making more Durable Structures". I am sure all the delegates will have a lot of value addition by the end of the program.

I personally take this opportunity to thank the Chief Patron, Associate Patrons, Sponsors, Exhibitors, Supporting Organizations, all the Advisors and the Members of the Organizing Committee for their constant support and guidance in making this event a grand success.

Looking forward to meet you all at Concrete Panorama and Deminar 2021.

Dr. R L Ramesh,
Honorary Secretary,
Bengaluru Centre.

ABOUT
ICI-BENGALURU CENTRE

ICI was born on 7th September 1982 with Head Quarter at Chennai:

- ICI - Life Membership (ALL INDIA) - 13023
- ICI - Centres - 44
- ICI - Student Chapters - 266
- ICI - Student Members - 9800
- ICI - Organizational Members – 350

ICI - Bengaluru Centre, Karnataka was started in the year 1984

- ICI - Life Membership (KARNATAKA): 787
- ICI - Centres : - 03
- ICI - Student Chapters : - 54
- ICI - Student Members : - 2500
- ICI - Organizational Life Members – 44

- ICI - Bangalore Centre, is successfully being run by an able adoptive and progressive managing committee since then. It is one of the active centres which conduct several programs every year. The membership is growing progressively day by day.

OBJECTIVES

- Promote growth of concrete construction and its sub-specialization.
- To disseminate information and train personnel by organizing seminars / conferences / workshops.
- Training programs for Fellow Members / Students and Corporate.
- Collaborate with National / International Agencies.
- Identify R & D problems of practical relevance.
- Arrange National and International Workshops, Conferences, Seminars, Deminars & Exhibitions
- Arrange Annual Lecture series on selected topics of relevance to Concrete Constructions
- To identify and recognize outstanding construction and outstanding performers in the field of Concrete Technology / Construction.

IMPORTANT EVENTS & PROGRAMS

- Monthly technical lectures, Endowment Lectures, National Workshops and Conferences.
- ICI-BENC was the first to organize ICI (Innovative World of Concrete) in 1993 – 2018 & ICI-ACECON in 2000.
- ICI-BENC is the first Centre among all the Centre's of ICI in India to start Concrete Panorama and Deminar (From 2009 to 2017 till date).
- Training modules on Concrete and Concrete Technology for various organizations and Institutions. These programs are conducted throughout the year to cater for the specific needs of the organizations concerned.

CONCRETE DAY AND CONSTRUCTION EXCELLENCE AWARDS

Indian Concrete Institute, Bengaluru Centre, Celebrates Concrete Day on 7th September. Every year this event is celebrated in a grand and befitting manner. Every year during the Concrete Day Celebrations, ICI-BENC in association with Ultratech Cements Limited recognizes outstanding and innovative structures built using concrete as main construction material and also identify and honour an individual who has worked for the cause of Concrete and rendered significant contributions to the research, development and application of concrete. Important Events & Programs from ICI-BENC Concrete Days Celebrations.

The prestigious awards instituted and given away during the Concrete Day Celebrations are :

- ICI-BENC - Ultratech Award for Outstanding Concrete Engineer / Technologist and Young Engineer of Karnataka
- ICI-BENC - Birla Super Award for Outstanding Concrete Structure of Karnataka
- ICI-BENC UltraTech Well Built Residential Awards for Districts
- ICI-BENC UltraTech Award for Outstanding Student Chapter
- ICI-BENC UltraTech Awards for Outstanding Thesis: Masters / Doctoral

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17	Er. Ravishankar M	Dr. Radhakrishna	2017 – 2019
18	Dr. Manjunatha L R	Dr. R L Ramesh	2019 – 2021

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Bengaluru Centre, Karnataka

ICI - Bengaluru Centre, Karnataka has 54 student chapters

1	Siddaganga Institute of Technology	Tumkur
2	M.V.J College of Engineering	Bangalore
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12	PES Institute of Technology	Bengaluru
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16	Sri Jayachamarajendra College of Engineering	Mysuru
17	East West Institute of Technology	Bengaluru
18	Bangalore Institute of Technology	Bengaluru
19	New Horizon College of Engineering	Bengaluru
20	Sri Venkateshwara College of Engineering	Bengaluru
21	East Point College of Engineering & Technology	Bengaluru
22	Rao bahadhur Y. Mahabaleshwarappa Engineering College	Bellari
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25	Dayananda Sagar College of Engineering	Bengaluru
26	RASTA - Centre for Road Technology	Bengaluru
27	Nitte Meenakshi Institute of Technology	Bengaluru
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53	Maharaja Institute Of Technology, Mysore	Mysuru-mandya
54	Gopalan College Of Engineering And Management	Bengaluru

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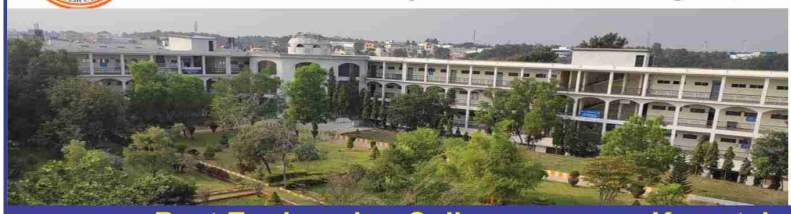

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प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

सत्यमेव जयते
Ministry of Housing & Urban Affairs
Government of India

स्वच्छ भारत
एक कदम स्वच्छता की ओर

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

LIGHT HOUSE PROJECTS

Light House Projects (LHPs) are model housing projects with houses built with shortlisted alternate technology suitable to the geo-climatic and hazard conditions of the region. This will demonstrate and deliver ready to live houses with speed, economy and with better quality of construction in a sustainable manner.

The period of construction is maximum 12 months from the date of handing over of sites to the construtction agency after all statutory approvals. Approvals will be accorded thriugh a fast track process by the concerned State Government.

These LHPs shall serve as LIVE Laboratories for different aspects of Transfer of technologies to field application, such as planning, design, production of components, construction practices, testing etc. for both faculty and students, Builders, Professionals of Private and Public sectors and other stakeholders involved in such construction.

Six Technology providers have been selected through rigorous online bidding process for construction of Light House Projects (LHPs) at six differnet locations in six states.

LOCATION	TECHNOLOGY	PROPOSED HOUSES
INDORE	PREFABRICATED SANDWICH PANEL SYSTEM	1,024
RAJKOT	MONOLITHIC CONCRETE CONSTRUCTION SYSTEM	1,144
CHENNAI	PRECAST CONCRETE CONSTRUCTION SYSTEM-PRECAST COMPONENTS ASSEMBLED AT SITE	1,152
RANCHI	PRECAST CONCRETE CONSTRUCTION SYSTEM-3D PRE-CAST VOLUMETRIC	1,008
AGARTALA	LIGHT GAUGE STEEL STRUCTURAL SYSTEM & PRE-ENGINEERED STEEL STRUCTURAL SYSTEM	1,000
LUCKNOW	STAY IN-PLACE FORMWORK SYSTEM	1,040

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Light House Project at AGARTALA

Technology

Light Gauge Steel Structural System
& Pre-engineered Steel Structural System

No. of Houses: 1000 DUs (Ground+6)

An already established System for building construction in Japan, Australia & North America; Light Gauge Steel Frame (LGSF) System uses factory made galvanized light gauge steel components. The components/sections are produced by cold forming method and assembled as panels at site forming structural steel framework upto G+3 building. LGSF is used in combination with pre-engineered steel structural system for buildings above G+3 for longevity, speedier construction, strength and resource efficiency.

Under this Light House Project, houses are being constructed using Light Gauge Steel Frame System (LGSF) with Pre-Engineered Steel Structural System.

Construction Process

The sequence of construction comprises of foundation laying, fixing of Pre-Engineered Steel Structural System, fixing of tracks, fixing of wall panels with bracings as required, fixing of floor panels, decking sheet, fixing of electrical & plumbing services and finally fixing of concrete walling panels with light weight concrete as infill. The other options of dry walling components such as sandwich panels with insulation material in between can also be used. Similarly, the floors can either by composite slab/deck slabs/precast hollow core slabs as per the need & requirements.

Special Features

- High strength to weight ratio. Due to light weight, significant reduction in design earthquake forces is achieved. Making it safer compared to other structures.
- Fully integrated computerised system with Centrally Numerical Control (CNC) machine primarily employed for manufacturing of LGSF sections provide very high Precision & accuracy.
- Construction being very fast, a typical four storeyed building can be constructed within one month.
- Structure being light, does not require heavy foundation
- Structural element can be transported to any place including hilly areas to remote places easily making it suitable for far flung regions including difficult terrains.
- Structure can be shifted from one location to other without wastage of materials.
- Steel used can be recycled multiple times
- The system is very useful for post disaster rehabilitation work.

Light House Project at CHENNAI

Technology

Precast Concrete Construction System – Precast Components Assembled at Site

No. of Houses: 1152 DUs (Ground+5)

An already established technology for building construction, Precast concrete construction is a system where the individual precast components such as walls, slabs, stairs, column, beam etc, of building are manufactured in plant or casting yard in controlled conditions. The finished components are then transported to site, erected & installed.

The technology provides solution for low rise to high rise buildings, especially for residential and commercial buildings.

Construction Process

The construction process comprises of manufacturing of precast concrete Columns, Beams and Slabs in steel moulds. The reinforcement cages are placed at the required position in the moulds. Concrete is poured and compaction of concrete is done by shutter/ needle vibrator. Casted components are then moved to stacking yard where curing is done for requited time and then these components are ready for transportation and erection at site.

These precast components are installed at site by crane and assembled together through in-situ jointing and/or grouting etc.

Special Features

- Nearly all components of building work are manufactured in plant/casting yard & the jointing of components is done In-situ leading to reduction in construction time
- The controlled factory environment brings resource optimization, improved quality, precision & finish
- The concrete can be designed industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBFS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resources
- Eliminates use of plaster
- Helps in keeping neat & clean construction site and dust free environment
- Optimum use of water through recycling
- Use of shuttering & scaffolding materials is minimal
- All weather construction & better site organization.

Light House Project at INDORE

Technology

Prefabricated Sandwich Panel System

No. of Houses: 1024 DUs (Stilt+8)

An already established System for building construction in China, Australia, African and Gulf countries, this factory made Prefabricated Sandwich Panel System is made out of cement or calcium silicate boards and cement mortar with EPS granules balls, and act as wall panels. These replace conventional brick & mortar walling construction practices and can be used as load-bearing and non-load bearing walling for residential and commercial buildings. For buildings higher than single storey, the system can be used either with RCC or steel framed structure.

Under this LHP, houses are being constructed using Prefabricated Sandwich Panel System with Pre-Engineered Steel Structural System.

In this system the EPS Cement Panels are manufactured at the factory in controlled condition, which are then dispatched to the site. The panels having tongue and groove are joint together for construction of the building.

Special Features

- Being dry walling system, brings speed in construction, water conservation (no use of water for curing of walling components at site).
- The sandwich panels have light weight material as core material, which brings resource efficiency, better thermal insulation, acoustics & energy efficiency
- Being light in weight results in lower dead load of building & foundation size.

Light House Project at LUCKNOW

Technology

PVC Stay In Place Formwork System

No. of Houses: 1040 DUs (Ground+13)

Already in use in Canada & Australia, the plant manufactured rigid poly-vinyl chloride (PVC) based polymer components serve as a permanent stay-in-place finished formwork for concrete walls. The formwork System being used acts as pre-finished walls requiring no plaster and can be constructed instantly.

This System is suitable for residential and commercial buildings of any height from low rise to high rise. In order to achieve speedier construction, strength and resource efficiency, the composite structure with Pre-Engineered Steel Structural System as structural members is being used in the present project.

Construction Process

Construction is done in a sequential manner where at first, the Prefabricated PVC Wall panels and Pre-Engineered Steel Structural Sections as per the design are transported to the Site. Then, these Sections are erected on the prepared foundation using cranes and required connections. Floor is installed using decking sheet. Once the structural frame and floor is installed and aligned, wall panels are fixed on decking floor. The pre-fabricated walling panels having provisions of holes for services conduits, are fixed along with the reinforcement & cavities inside the wall panels are filled with concrete. Upon installment of wall panels, flooring and ceiling, the finishing work is executed.

Special Features

- Having formwork already as part of system, the construction of building is faster as compared to conventional buildings. The formwork needs some support only for alignment purpose.
- In case of concrete as filling material, the curing requirement of concrete is significantly reduced, thus saving in precious water resources.
- The formwork system does not have plastering requirement & gives a very aesthetic look.

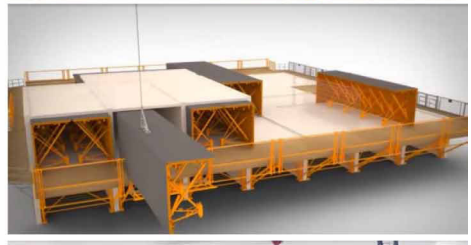
Light House Project at RAJKOT

Technology

Monolithic Concrete Construction using Tunnel Formwork

No. of Houses: 1144 DUs (Stilt+13)

In 'TunnelForm' technology, concrete walls and slabs are cast in one go at site giving monolithic structure using high-precision, re-usable, room-sized, Steel forms or moulds called 'TunnelForm'. An already established System for building construction in many countries, this system intends to replace the conventional RCC Beam-Column structure which uses steel/ plywood shuttering. 'TunnelForm' system uses customised engineered steel formwork consisting of two half shells which are placed together and then concreting is done to form a room size module. Several such modules make an apartment.



Construction process

- Stripping of the formwork from the previous day.
- Positioning of the formwork for the current day's phase, with the installation of mechanical, electrical and plumbing services.
- Installation of reinforcement in the walls and slabs.
- Concreting

Special Features

- Facilitating rapid construction of multiple/ mass modular units (similar units)
- Making structure durable with low maintenance requirement
- The precise finishing can be ensured with no plastering requirement
- The concrete can be designed to use industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resource
- Being Box type monolithic structure, it is safe against horizontal forces (earthquake, cyclone etc.)
- The large number of modular units bring economy in construction.

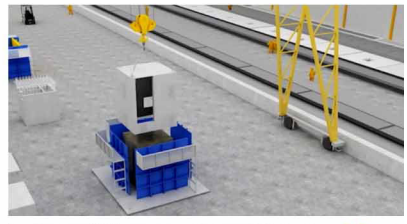
Light House Project at RANCHI

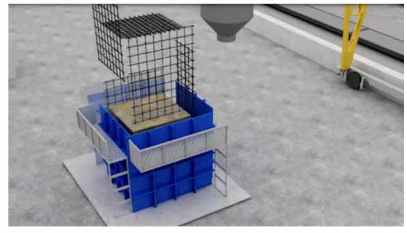
Technology

Precast Concrete Construction System – 3D Volumetric

No. of Houses: 1008 DUs (Ground+8)

An already established System for building construction in Europe, Singapore, Japan & Australia, this 3D Volumetric concrete construction is the modern method of building by which solid precast concrete structural modules like room, toilet, kitchen, bathroom, stairs etc. & any combination of these are cast monolithically in Plant or Casting yard in a controlled condition. These Modules are transported, erected & installed using cranes and push-pull jacks and are integrated together in the form of complete building unit. Subject to the hoisting capacity, building of any height can be constructed using the technology.





Construction Process

Sequential construction in the project here begins with keeping the designed foundation of the building ready, while manufacturing of precast concrete structural modules are taking place at the factory. Factory finished building units/modules are then installed at the site with the help of tower cranes. Gable end walls are positioned to terminate the sides of building. Pre stressed slabs are then installed as flooring elements. Rebar mesh is finally placed for structural screed thereby connecting all the elements together. Consecutive floors are built in similar manner to complete the structure.

Special Features

- About 90% of the building work including finishing is complete in plant/casting yard leading to significant reduction in construction & occupancy time
- The controlled factory environment brings resource optimization, improved quality, precision & finish
- The required concrete can be designed using industrial by-products such as Fly Ash, Ground granulated blast furnace slag (GGBS), Micro silica etc. resulting in improved workability & durability, while also conserving natural resources. In this project Ground granulated blast furnace slag & silica fume is being used in concrete.
- With smooth surface it eliminates use of plaster
- The monolithic casting of walls & floor of a building module reduces the chances of leakage
- The system has minimal material wastage (saving in material cost), helps in keeping neat & clean construction site and dust free environment
- use of Optimum quantity of water through recycling
- Use of shuttering & scaffolding materials is minimal
- All weather construction & better site organization.

Durable Aluminium Reinforced Environmentally-friendly Concrete Construction (DARE2C)

Harald Justnes, SINTEF Community, Trondheim, Norway

1. Introduction

Cement is a key binder component of concrete production in the building industry. It is a complex hydraulic binder, made up of four main clinker components; alite (Ca_3SiO_5), belite (Ca_2SiO_4), tricalcium aluminate ($Ca_3Al_2O_6$) and ferrite (Ca_2AlFeO_5), which are milled together with gypsum to regulate setting time. In recent years, the production of cement has been identified as the third largest emitters of carbon dioxide (CO_2), accounting for approximately 5 to 8% of the total global anthropogenic emissions, with 60% coming from decomposition of limestone in the raw meal and 40% from fuel to reach clinkerization temperatures of 1450°C for a pure Portland clinker. Four main methods are currently in place to mitigate this challenge; i) switching from fossil fuels to alternative fuels, ii) increase efficiencies in factories, iii) implementation of supplementary cementitious materials (SCMs) replacing cement clinker [1] and iv) carbon capture and storage (CCS) [2]. Among which, clinker partially replaced by SCMs is the most promising on a short term [1], whereby significant reduction in CO_2 emission could be expected depending on how much emission is associated with the SCM (transport, calcination energy etc.). Replacing cement with SCM will also reduce the amount of raw meal needed per unit cement and increase the cement production volume of a cement plant. Most of the cement produced today has clinker replaced with SCMs with an average global clinker factor of 0.85 in 2003 [3], but higher clinker replacement with a greater variety of SCMs is expected in the near future. The potential SCMs of the future include combustion ashes, slag, calcined clay and limestone. Fly ash is commonly employed in current cements with replacement of 20% in Norway. Calcined clay or marl is a new and upcoming SCM due to its abundance as increased clinker replacement demands large volumes of available SCMs. Additionally, previous studies displayed that calcined marl is a potential SCM up to a replacement level of 50% in terms of equal 28 day strength according to Justnes [1], but generally it is limited to < 35% replacement if sufficient alkalinity is to be maintained to protect steel from corroding in the long run.

The most common reinforcement for structural concrete is rebars made of steel. At the same time the most common degradation mechanism of reinforced concrete is corrosion of the steel initiated by carbonation (i.e. CO_2 from the air diffuse in and lower the pH by neutralization) or by chlorides exceeding a critical limit in spite of maintained pH. Thus, there as a need for concrete reinforcement that will not corrode, but at the same time being composed of common chemical elements since a gross volume of 1010 m3 concrete is produced annually world-wide. “Stainless steel” exists that will not corrode, but there is “not enough chromium in the world” to make a significant replacement feasible and it is rather pricy. Some efforts have been made to make rebars out of fibre reinforced plastic (FRP), but these tend to have a brittle failure unlike metals being ductile. Karlsson [4] made a review and evaluation of alternative concrete reinforcement. Naturally, aluminium was not a part of this evaluation since it will be degraded by the high pH of regular concrete and can only function in a sufficiently low pH concrete. On the other hand, aluminium is a very common element in earth’s crust.

The main durability design of concrete today is in relation to preventing the steel reinforcement from corroding. The major degradation mechanisms; chloride ingress and carbonation, does not jeopardize the integrity of the concrete binder itself. Steel needs the high pH of conventional concrete to be passive towards corrosion while aluminium metal will be corroded by high pH and develop hydrogen gas. Environmentally friendly concrete is often designed by either using blended cement where maximum 35% of the clinker is replaced by supplementary cementitious materials (SCMs) to secure the presence of calcium hydroxide over time that will buffer a pH of 12.5 passivating steel, or by replacing cement in concrete mixes with corresponding amounts of SCM. In order to secure long service life for steel reinforced concrete, low w/c is used for low permeability often leading to much higher strength than required. Low w/c can also create complications in the construction phase as lower workability is calling for use of super-plasticizing admixtures. Using more cement to attain low w/c can create higher temperature and subsequent thermal cracking risk generated by hydration heat as well as chemical shrinkage. The required compressive strength for the bulk of concrete today is still in the range of 25-30 MPa (B25).

The DARE2C concept is to make environmental friendly concrete with > 50% cement replacement by a combination of SCMs where some are so pozzolanic active that the pH is kept so low that the concrete can be reinforced with aluminium metal rods without formation of hydrogen gas. The w/c can then be so high that it is only determined by required compressive strength for construction. Then workability should not be a problem and neither hydration generated heat. Permeability is not important as aluminium metal is resilient to atmospheric CO_2 and chlorides (when alloyed with 5% Mg), and high initial permeability is in fact beneficial for the concrete to carbonate as fast as possible to reduce the carbon footprint further and lower the pH further for the long run. The concrete cover over the reinforcement can be made much thinner (20 mm) than today (50-70 mm)

reducing weight and further improving the carbon footprint by using less concrete. Justnes [5] discussed the options of making a concrete with lower pH than usual ranging from large cement replacement (>50%) to calcium sulphoaluminate-belite cement systems with a smaller content of pozzolana.

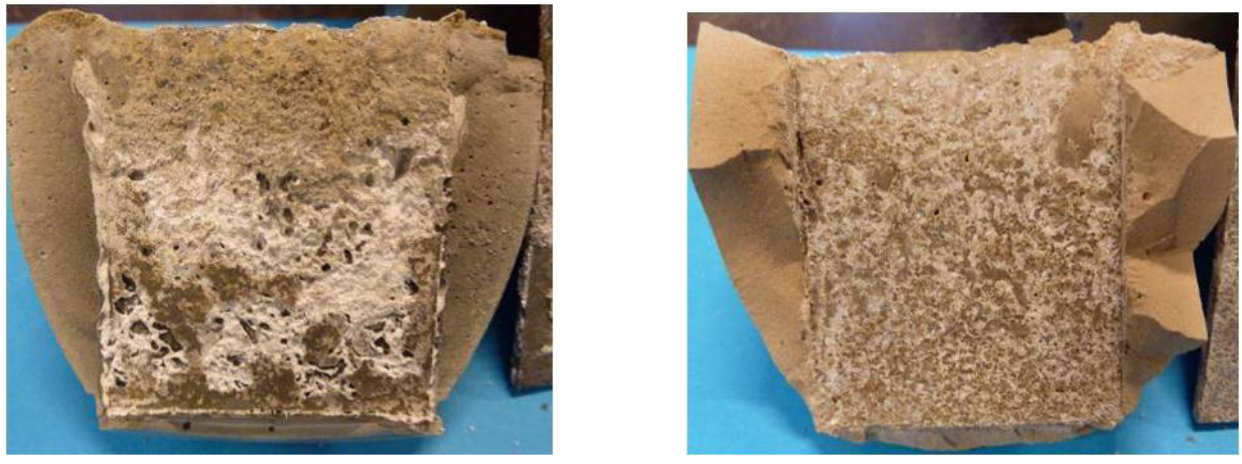
2. Proof of the DARE2C concept

As a proof of concept, two paste mixes with w/c = 0.60 were made with 100% ordinary Portland cement and 50% calcined marl [6] replacing cement. These pastes were poured into a plastic cup and an aluminium plate placed in each of them as shown in Fig. 1. The paste of pure cement separated and after a few minutes hydrogen gas started to bubble vigorously along the aluminium plate as seen from the left side of Fig. 1, while for the mix with 50% calcined marl some water was added on top for better visualization, but only a few small bubbles were observed. After the pastes had hardened, the samples were split and the imprints of the front and back of the aluminium plates on the pastes are shown in Fig. 2. It is clearly much more cavities in the OPC sample next to the plate, while only a few small gas voids are seen on the interface for the paste with 50% calcined marl. One cannot rule out that the minor gas voids are due to entrained air by the high shear mixer, and the only way to find out is to capture and measure the evolved gas volume [7] or to detect hydrogen specifically by a gas chromatograph.

If one place an aluminium bar in pure OPC paste, it will be totally corroded until there is just gibbsite, Al(OH)3, left (see Eq. 5) as shown in Fig. 3. Placing the same bar in paste where 55% cement has been replaced by calcined bar render a non-corroded bar as seen from Fig. 3 as white corrosion products would easily have been spotted against the red-brown paste.

Reference paste (w/c = 0.60) **50/50 cement/calcined marl (w/c = 0.60)**

Fig. 1 - Aluminium plates inserted in pastes of different composition for gas observation.



Reference, split front **50% calcined marl, split front**

Reference, split back

50% calcined marl, split back

Fig. 2. - Interfaces between aluminium plate inserts and pastes after hardening showing the difference in cavities formed by hydrogen gas evolution.

Fig. 3 ¬- Al/5% Mg alloy rods placed in OPC paste (left) and totally converted to gibbsite after 28 days curing in moist condition, while same rod placed in paste where OPC is replaced with 55% calcined marl is in pristine condition without any corrosion products in its imprint (right).

3. Testing of concrete reinforced with aluminium bars

3.1. Concrete formulation for low strength concrete

The basic binder was made out of 45% low-alkali CEM I cement 55% marl calcined at 750°C, with chemical composition as given in Tab. 1. The specific surface of the cement (Blaine) was 388 m^2/kg while the specific surface (BET) of the calcined clay was 38 m^2/g. Pastes of the same binder were blended in a high shear mixer to a water-to-powder ratio of 0.7. The pH evolution of this paste is shown in Fig. 4 together with a paste where also a soluble magnesium salt (0.57% Mg^{2+} of binder mass) was added.

Table 1. Chemical composition (%) of the cement and calcined marl and kaolinitic clay (MK)

Oxide	CEM I	Marl	MK
SiO2 (%)	21.12	49.03	60.6
Al2O3 (%)	4.60	16.14	30.0
Fe2O3 (%)	3.77	9.41	3.4
CaO (%)	63.21	10.55	0.1
MgO (%)	1.71	2.47	0.4
SO3 (%)	3.87	-	-
K2O (%)	0.40	2.38	3.2
Na2O (%)	0.35	0.78	-

The purpose of the calcined marl was to consume all calcium hydroxide produced by the cement and render all alkalis as aluminate or silicate and to prevent them for regenerating as hydroxides as explained in the alkali cycle for catalytic pozzolanic reaction exemplified principally (i.e. not necessarily correct ratio between the different oxides in the compounds) for aluminosilicate (AS) in reaction 1;

AS (s) + 2 (N,K)H (aq) → (N,K)SH (aq) + (N,K)AH (aq)

↑ "alkali loop" + (1)

CSH (s) + CAH (s) + (N,K)H (aq) ← CH (aq or s)

where cement chemist's short hand notation is used; C = CaO, H = H_2O, K = K_2O, N = Na_2O, S = SiO_2 and A = Al2O3. The alkali hydroxides dissolves alumina and silica from the aluminosilicate that react with calcium hydroxide (CH) to amorphous calcium silica hydrate (CSH) gel and crystalline calcium aluminate hydrates (CAH) as binder. After reaction with CH the alkali hydroxides are regenerated, and the loop continues until all calcium hydroxide is consumed and they end up as alkali silicate and alkali aluminate that in theory should not attack the aluminium metal in the rebars even though they result in high pH. Justnes et al [8] showed that paste where cement is replaced with 50% calcined marl showed no traces of calcium hydroxide after 2 years by XRD.

Aluminium metal forms a dense layer of Al_2O3 in contact with air that prevents further oxidation (or corrosion). This layer may dissolve by alkali hydroxides and open up for further corrosion evolving hydrogen gas;

Oxidation: $Al (s) + 4\ OH^- = Al(OH)_2O^- + H_2O + 3\ e^-$ $E^0 = +2.333$ V (2)

Reduction: $2\ H_2O + 2\ e^- = H_2\ (g) + 2\ OH^-$ $E^0 = -0.828$ V (3)

Total: $2\ Al\ (s) + 2\ OH^- + 4\ H_2O = 2\ Al(OH)_2O^- + 3\ H_2\ (g)$ $E^0 = +1.502$ V (4)

According to the total reaction in Eq. 4, there will be a net consumption of one hydroxide ion per aluminium oxidized, or none if gibbsite, Al(OH)3, is precipitated rather than the dissolved anion;

$2\ Al\ (s) + 6\ H_2O = 2\ Al(OH)3 + 3\ H_2\ (g)$ (5)

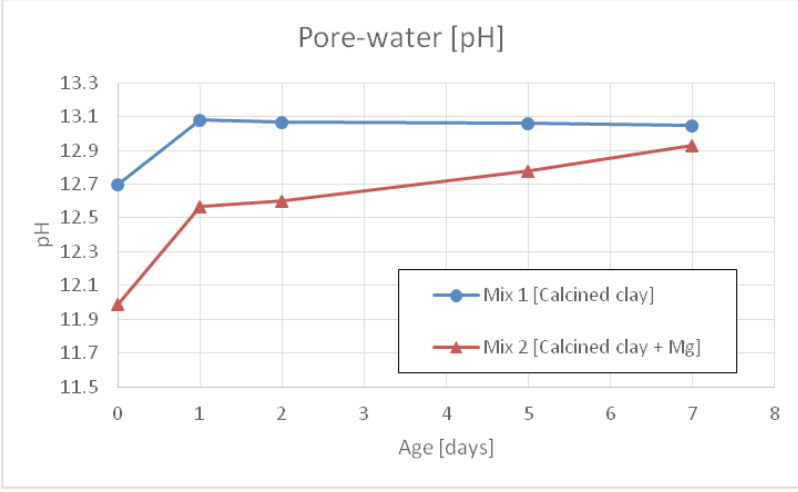


Fig. 4 - pH evolution as a function of sealed curing age at 20°C. Mix 1 = paste with 45% CEM I, 55% calcined marl and w/p = 0.70, while Mix 2 = mix 1 added additional 0.57% Mg2+ of powder mass.

The purpose of adding a soluble magnesium salt was to lower the initial pH by precipitating brucite;

$Mg^{2+} + 2OH^- = Mg(OH)_2\ (s)$ (5)

By using a magnesium salt, the alkali hydroxides would then in theory become neutral alkali salts. Brucite has equilibrium pH 10.5. There would also be a chance that hydrotalcite, $Mg6Al_2(OH)18{\bullet}3H_2O$, would form in the longer run and further reduce pH by binding more hydroxyl ions. However, as can be seen from Fig. 4, the pH of the mix with magnesium salt increases over time after the first initial reduction. This is in retrospective explained by ion exchange between OH- and X- by AFm phases like hydrocalumite in Eq. 6;

$Ca4Al_2(OH)12(OH)2{\bullet}4H_2O\ (s) + 2NaX\ (aq) = Ca4Al_2(OH)12X2{\bullet}4H_2O\ (s) + 2NaOH\ (aq)$ (6)

This is yet to be confirmed by X-ray diffraction on corresponding paste without aggregate. The abrupt pH increase from the first data point (fresh state) to the second (hardened) is due to consumption of water to hydrates and thereby higher concentration of soluble species, but release of alkalis from the reacting clay cannot be ruled out as the pozzolanic reaction starts. The initial pH of pure CEM I without calcined marl was 13.5.

The composition of the concrete is given in Table 2, and a soluble magnesium salt (0.57% Mg_2+ of binder mass) was also added. The compressive strength, splitting tensile strength and static E-modulus of cylinders (Ø100 mm·200 mm) was measured after 28 days curing under wet burlap and plastic wrapping to avoid drying, and the results listed in Table 3. The concrete was made in two batches and used to cast 18 cylinders and three 150•250•1100 mm beams reinforced with Ø10 mm aluminium bars alloyed with 5% magnesium. The beams were tested in a 4-point bending and the crack pattern compared to finite element calculations (not reported here). After the bending test, one of the beams were cut and split to inspect the bars for corrosion. As seen from Fig. 5, there was no sign of corrosion on the bars (left image) and the imprint in the concrete (right image) was clean without corrosion products. Prior to these bigger batches, a smaller trial mix was made, and a number of 10 cm cubes cast in steel moulds. The strength evolution for the trial mix versus curing age at 98% RH and 20□C is plotted in Fig. 6, and the temperature evolution in a 3.5 litre Styrofoam mould (10 mm wall thickness) shown in Fig. 7 indicating a setting time of 4.5 h (270 min).

Table 2: Concrete composition

Component	Mass (kg/m^3)
CEM I	143.9
Calcined marl	175.9
Free water	223.9
Adsorbed water	5.7
0-8 mm Granite sand	970.9
8-16 mm Granite gravel	702.4
SIKA Viscocrete RMC-315	1.92

Table 3: Mechanical properties of concrete cylinders

Property	No. samples	Value
Density (kg/m3)	12 from 2 batches	2328±16
Compressive strength (MPa)	8 from 2 batches	22.3±0.9
Splitting tensile strength (MPa)	4 from 2 batches	2.3±0.2
Dynamic E-modulus (GPa)	4 from 2 batches	20.3±0.9

Note that the concrete target strength was around 25 MPa and that it was deliberately made porous with a water-to-binder ratio of 0.7. It can of course be made stronger by simply lowering the water content and increasing the super-plasticizer dosage a bit from the current 0.6% of binder mass as shown in the next section. Justnes et al [8] showed that mortar where cement was replaced with 50% calcined marl and the water-to-binder ratio was 0.55 achieved the same compressive strength has mortar with 100% cement and that the compressive strength continued to increase until the last measurement at 2 years age in spite of no calcium hydroxide present at 28 days age.

Fig. 5 - Split concrete beam at 40 days age showing that aluminium bars (left image) are not corroded (including a T-profile bar in same alloy perpendicular to them) and that the imprints in the concrete (right image) are free from corrosion products.

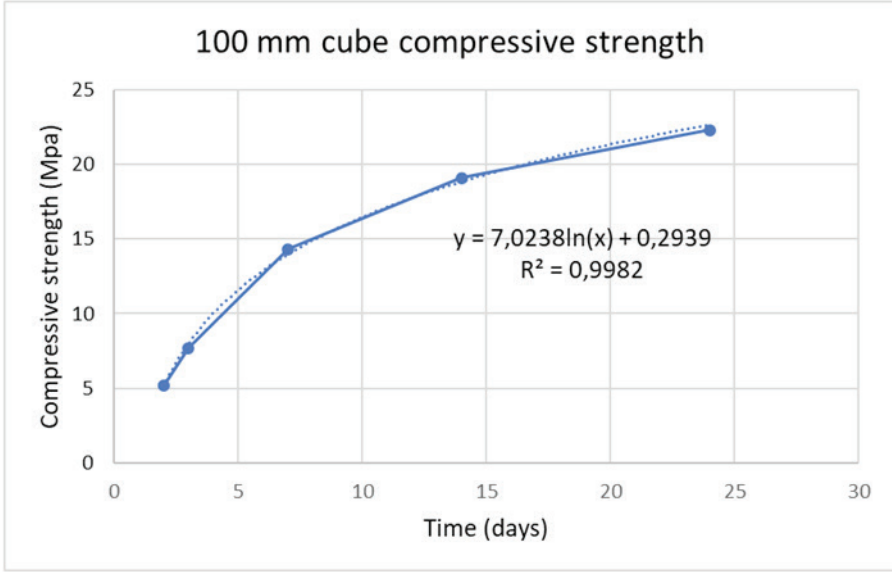


Fig. 6 - Compressive strength of concrete as a function of curing time at 98% RH and 20□C.

The aluminium rebars are produced by an extrusion process. The screw extrusion process is patented by Werenskiold et al [9]. A prototype extruder along with fundamental knowledge of the process have been developed to a level that allows industrial implementation. Compared to the traditional process route based on re-melting and extrusion, direct screw extrusion of scrap material represents a significant reduction in energy consumption according to Duflou et al [10]. Moreover, this process is well suited for utilization of swarf material from material removal processes such as cutting, milling and turning that is commonly of less value than other scrap types. This is further contributing to the environmental friendliness of the overall DARE2C concept.

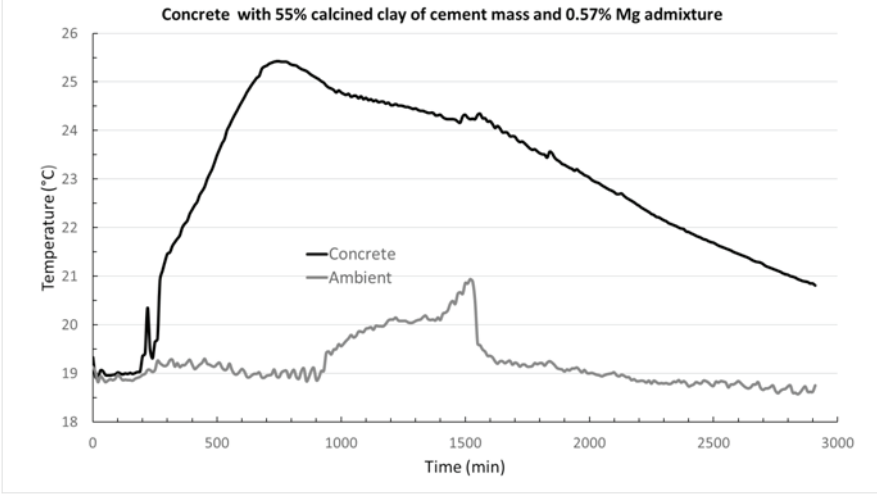


Fig. 7 - Temperature evolution in concrete in 3.5 litre Styrofoam mould versus ambient.

Since the DARE2C concept is to let the concrete carbonate as fast as possible for both the sake of environment and to ensure long term/low pH stability of aluminium, a test was made on mortar to see the effect of carbonation on strength.

The compressive strength of carbonated mortar versus non-carbonated mortar was measured to 20.2±0.2 and 23.7±0.5, respectively. The mortar composition was 0.45 parts CEM I, 0.55% calcined clay and w/p = 0.7 cured for 28 days at 90% RH and 20°C for 28 days before one set of 3 prisms were carbonated through in a 5% CO_2 chamber with 60% RH and the other set just stored at 60% RH in a closed box for same length of time. According to Justnes et al [11] the strength reduction is higher for cements blended with alumina containing SCMs than for OPC since the higher amount of calcium aluminate hydrates formed [12] will lead to a porosity increase when they carbonate, unlike calcium hydroxide leading to a volume decrease upon carbonation.

The molar volume change (ΔVm) for ettringite (AFt) carbonating to calcite, gibbsite, gypsum and liquid water;

$$Ca_3Al_2O6{\cdot}3CaSO4{\cdot}32H_2O\ (s) + 3H_2CO3\ (aq) = 3CaCO_3\ (s) + 2Al(OH)_3\ (s) + 3CaSO_4{\cdot}2H_2O\ (s) + 26H_2O \quad (7)$$

$\Delta Vm = 3 \cdot 36.93 + 2 \cdot 32.22 + 3 \cdot 74.50 - 705.91 = -307.18$ cm^3/mol AFt

For calcium monosulphoaluminate hydrate (AFm) carbonating to calcite, gibbsite, gypsum and liquid water;

$Ca_3Al_2O6 \cdot CaSO_4 \cdot 12H_2O\ (s) + 3\ H_2CO_3\ (aq) = 3\ CaCO_3\ (s) + 2\ Al(OH)3\ (s) + CaSO_4 \cdot 2H_2O\ (s) + 10\ H_2O$ (8)

$\Delta Vm = 3 \cdot 36.93 + 2 \cdot 32.22 + 74.50 - 308.94 = -59.21$ cm3/mol AFm

For calcium monocarboaluminate hydrate carbonating to calcite, gibbsite and liquid water;

$Ca_3Al_2O6 \cdot CaCO_3 \cdot 11H_2O\ (s) + 3\ H_2CO_3\ (aq) = 4\ CaCO_3\ (s) + 2\ Al(OH)_3\ (s) + 11\ H_2O$ (9)

$\Delta Vm = 4 \cdot 36.93 + 2 \cdot 32.22 - 261.28 = -49.12$ cm^3/mol monocarboaluminate

For calcium hemicarboaluminate hydrate carbonating to calcite, gibbsite and liquid water;

$Ca_3Al_2O6 \cdot \frac{1}{2}CaCO_3 \cdot \frac{1}{2}\ Ca(OH)2 \cdot 11.5H_2O\ (s) + 3.5\ H_2CO_3\ (aq) = 3.5\ CaCO_3\ (s) + 2\ Al(OH)_3\ (s) + 12\ H_2O$ (10)

$\Delta Vm = 3.5 \cdot 36.93 + 2 \cdot 32.22 - 284.36 = -90.67$ cm^3/mol hemicarboaluminate

The same increase in porosity and decrease of strength also holds for other SCMs high in alumina. For mortars with binders based on 30% siliceous fly ash and 5% limestone stabilizing ettringite cured for 56 days [11], the water vapour diffusion coefficient, kd (10^{-12} kg/Pa•m•s), increased upon carbonation (from 0.41±0.09 to 3.06±0.04) unlike mortar based on OPC (changed from 0.76±0.10 to 0.59±0.10).

3.2. Concrete formulation for higher strength concrete

The recipe for a higher strength concrete is given in Table 4 where we used another type of clay being kaolin rich (denoted MK in Table 1). The water-to-powder ratio is now 0.54. The compressive strength for 100 mm cubes at 28 d was 43.9±1.2 MPa and for Ø10•200 mm cylinders 36.5±1.0 MPa for 3 parallels. The splitting tensile strength was 3.4 MPa and the E-modulus was 30.9 GPa after 1st and 32.9 GPa after 2nd loading. The compressive strength evolution for the cubes is shown in Fig. 8 for a logarithmic time scale.

Table 4: Concrete composition

Component	Mass (kg/m^3)
CEM I	156.4
Calcined clay (MK)	178.7
Silica fume	22.3
Limestone filler	14.9
Free water	195.6
Adsorbed water	6.0
0-8 mm Granite sand	1037.7
8-16 mm Granite gravel	720.4
SIKA Viscocrete RMC-315	2.2

This concrete recipe was developed for consideration of loadbearing structures, and as a start to show the stability of aluminium metal, a bench was made as shown in Fig. 9. Since aluminium does not corrode in this concrete mix and not in air, decorative or practical details can be made where the aluminium reinforcement comes out of the concrete and can be used for rails etc.

The compressive strength evolution for 40•40•160 mm mortar prisms with same binder recipe as for the concrete recipe in Table 4, but with graded norm-sand, is plotted in Fig. 10. The compressive strength at 1 day is 4x higher when cured at 38°C than at 20°C.

4. Structural considerations

The E-modulus of pure aluminium metal (70 GPa) is 1/3 of steel (210 GPa), but the density of aluminium (2.70 kg/l) is also about 1/3 of iron (7.87 kg/l). The ultimate tensile strength of pure aluminium is 110 MPa, while it for rebar steel is 400 MPa, but aluminium can be alloyed to approach steel in tensile strength. To put it simply, a full replacement with same design for e.g. a beam means three times more volume aluminium reinforcement than steel while the weight will be the same. However, some of this may be alleviated by designing the aluminium rebars differently.

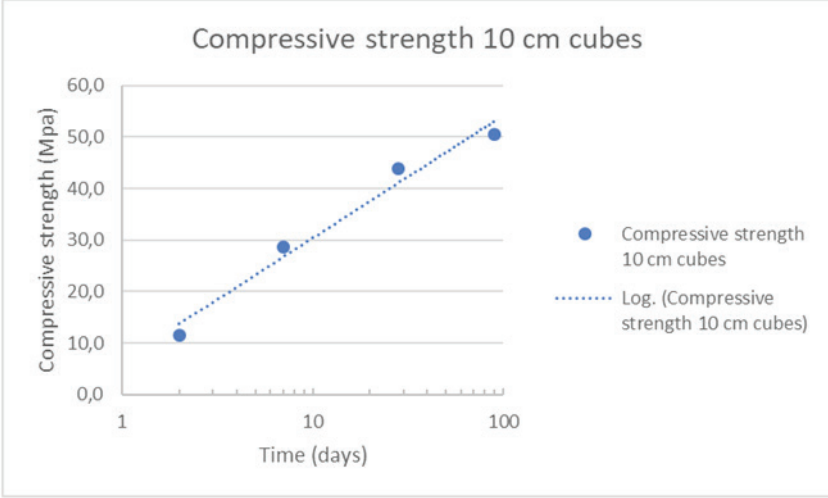


Fig. 8 – Compressive strength evolution for 100 mm cubes from 2-91 days.

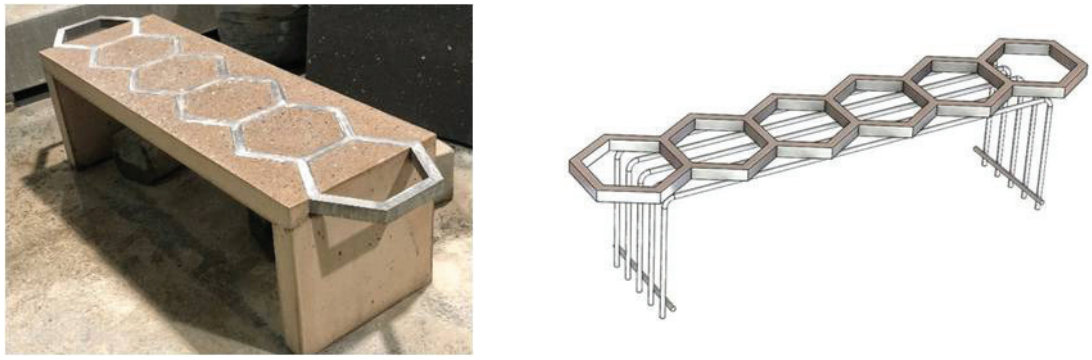


Fig. 9 – Bench with polished top surface and reinforcement configuration in aluminium

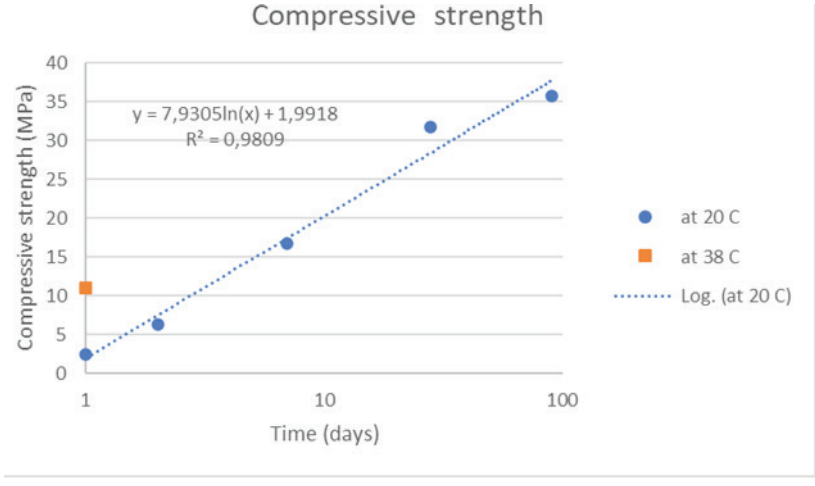


Fig. 10 – Strength evolution for mortar with same binder recipe as in Table 4.

As comparison, FRP rebars made with glass, basalt or carbon fibres have E-modulus of 45, 60 and 145 GPa, and tensile strength of 700, 800 and 2000 MPa, respectively, according to Karlsson [4]. In the SEACON project [13] a bridge is built using FRP rebars demonstrating the feasibility of constructing with rebars with such lower E-modulus than steel.

Another issue is the difference in linear thermal expansion coefficient. Concrete has 6-14•10^{-6} m/m•K, while pure iron and pure aluminium has 10 and 22•10^{-6} m/m•K, respectively. The thermal expansion of aluminium can be reduced by alloying (in particular by silicon). As comparison, glass fibre reinforced polyester has a linear thermal expansion coefficient of 25•10^{-6} m /m•K. The consequence of difference in thermal dilation between reinforcement and binder will be an issue for further research.

5. Outlook

Formulating stable concrete reinforced with aluminium metal bars can lead to the following benefits in addition to using an environmentally friendly binder with high content of SCMs;

- Maintenance free reinforced concrete (i.e. no carbonation or chloride induced corrosion)
- Any microcracks caused by drying shrinkage etc will not jeopardize reinforcement durability
- Superior sulphate resistance when alumina containing SCMs like calcined marl is used [5]
- Alkali reactive aggregate can be used due to alkali binding [14] or soluble aluminates from clay inhibiting silica dissolution [15, 16]
- Seawater can be used as mixing water when reinforcement is Al alloyed with Mg
- The best strength accelerator, calcium chloride, can be used when reinforcement is aluminium alloyed with Mg (so called sea-water resistant aluminium for boats)
- Much less cover over rebar needed (save 30 mm in concrete cover), probably only 20 mm needed for proper anchoring of reinforcement with concrete.
- Al-reinforced concrete will have significantly lighter unit weight (reduced “dead-weight”)
- Higher w/c allowed giving more permeable concrete leading to
    1. Easier to cast as the concrete will need less plasticizers or none
    2. Faster carbonation leading to binding of CO^2 and further reduction of Carbon-footprint
    3. Less thermal expansion/contraction in monolithic concrete

6. Conclusions

A new concept of durable and environmentally friendly aluminium reinforced concrete is described. Being able to formulate concrete where aluminium metal will not be attacked by the concrete binder constituents, a maintenance free reinforced concrete with very long service life may be at hand.

Binder paste and concrete has been studied where 50-55% cement is replaced by calcined marl or clay with the following findings:

1. Aluminium plates immersed in such paste does not appear to evolve hydrogen gas as for 100% CEM I paste.
2. Addition of soluble magnesium salts maybe used to lower the initial pH of fresh paste, but the pH approaches the mix without after 14 days curing when using alumina containing SCMs due to possible anion exchange with hydrocalumite
3. Concrete with water-to-binder ratio 0.7 can be made without flash setting (sets at 4.5 h) and reach a compressive strength of 22 MPa at 28 days, but can be made stronger by reducing w/c (w/c = 0.54 gives 44 MPa at 28 days)
4. Concrete beams reinforced with aluminium metal bars showed no signs of cracking at 40 days nor any corrosion of the bars by visual inspection

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Flexure Behavior of Reinforced Masonry Assemblages Under Monotonic and Cyclic Loading

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ABSTRACT : The primary reason for collapse of unreinforced masonry buildings during earthquakes is out-of-plane flexural failure of walls which jeopardizes the gravity load carrying capacity. Reinforcing masonry in the vertical direction along with continuous horizontal bands for establishing integral connection of various walls of the building will ensure overall stability of the building. This paper addresses the issue of flexural behavior of reinforced masonry assemblages under monotonic and cyclic loading. Flexure studies have been conducted on (1) Stretcher bond (110 mm depth) and English bond (230 mm depth) masonry beams with near surface mounted reinforcement consisting of galvanized iron (GI) wire of 4 mm diameter and high yield strength bars of 5.35 mm and 10.0 mm diameter and (3) Rat-trap bond masonry beams of 230 mm depth reinforced at the middle of the depth with GI wires of 4 mm diameter. Totally twenty beams were tested, ten under monotonic four point bending and remaining under reverse cyclic three-point bending. The cyclic loading was of sinusoidal pattern with increasing displacement amplitude and decreasing frequency (1.0 Hz to 0.2 Hz). The parameters considered were yield tensile strength of reinforcement and percentage area of reinforcement. However, for all the beams the percentage area of reinforcement provided was a fraction of the area of reinforcement required for balanced section. The primary purpose of reinforcing masonry was to enhance ductility and energy absorption capacity and not strength. From load-displacement and moment-curvature response, displacement ductility and curvature ductility were found to be in the range of 1.1 to 14.5 and 1.3 to 12 respectively. The equivalent hysteretic damping at failure was found to be in the range of 5% to 20%. It was observed that there is steep reduction in stiffness (degradation) up to 10% of normalized displacement and remains fairly constant thereafter till failure.

KEYWORDS: flexure, cyclic in-plane shear, reinforced masonry, ductility, hysteretic damping, stiffness degradation

INTRODUCTION

Typically, the walls of a masonry building are subjected to a combination of in-plane and out-of-plane loading during a seismic event. Rarely, the masonry walls can experience pure in-plane or out-of-plane seismic loading. The damage to masonry walls may initiate either in in-plane mode or in out-of-plane mode. However the final failure of the walls, largely, is due to out-of plane collapse (Boussabah and Bruneau, 1992). Unlike in-plane damage, out-of-plane failure jeopardizes the gravity load carrying capacity of the URM walls (Bruneau, 1994, Griffith et al., 2003), hampering overall stability of the masonry buildings. Consequently, out-of-plane collapse of the masonry walls is the key reason for loss of life in seismic events (Ehsani et. al., 1999). Additionally, the roofs of masonry buildings are often built with deformable structural elements. The deformable roofs fail to transfer the load to in-plane walls and walls transverse to the direction of earthquake get flexed. The out-of-plane response of such walls and second order P-Δ effects govern the failure of such buildings and stability may be endangered (Porto et al., 2011).

Traditional approaches of strengthening URM such as ferro-cementing, reinforced plastering, shortcreting, injecting cementing materials in the crack, center core techniques and post-tensioning have resulted in marginal improvement in out-of-plane behavior of masonry walls. Consequently, fiber reinforced polymer (FRP) strengthening and provision of steel reinforcement, has emerged as effective alternatives to strengthen masonry wall against out-of-plane (flexural) loads. Provision of reinforcing material demonstrably improves performance of the masonry wall under flexure (Fodi and Bodi, 2011). Knowledge of behavior of strengthened masonry, under out-of-plane cyclic loads, has been gathered by past research. Drysdale and Hamid (2008) reported that prior to cracking, steel reinforced masonry walls behave as URM walls and after cracking stiffness of the wall gets reduced invoking the contribution of vertical reinforcement. The steel reinforced masonry walls exhibit good deflection, ductile failure with excellent energy dissipation capacity (Drysdale and Hamid, 2008, Hamid et al., 1990, Sveinsson et al., 1985). Hamid et al. (1990) reported that the percentage and location of vertical steel have an effect on load deflection behavior, strength and ductility of the wall.

Conventionally (and in the above studies), the vertical reinforcing steel bars are provided at the midthickness of the masonry walls (termed as core reinforcement). Such arrangement of reinforcement in masonry renders half of the masonry wall thickness ineffective in resisting bending moments due to seismic actions (Raghunath et al., 2012, Rao et al., 2004). Furthermore, due to reversal of stresses under seismic action, tensile cracks initiate on both faces of the masonry walls. The provision of

reinforcement at core of the masonry wall results in development of few flexural cracks that grow rapidly and reach core reinforcement, rendering insufficient ductility (Raghunath et al., 2010, Jagadish et al., 2002). Jagadish et al. (2002, 2003) suggested an improved way of reinforcing masonry walls in vertical direction, termed as 'containment reinforcement'. The containment reinforcement was suggested to be provided in one of the following two ways (Raghunath et al., 2012),

a) The vertical reinforcement can be provided on the surface of masonry wall and held in the position by horizontal ties at every/alternate bed joints. Horizontal ties will ensure integral behavior of masonry and containment reinforcement. However, exposed containment reinforcement needs protection against corrosion. (Figure 1)

b) Grooved masonry unit can be laid in such a way that a continuous vertical groove is created to accommodate the vertical reinforcement. The vertical groove can later be grouted (Figure 2).

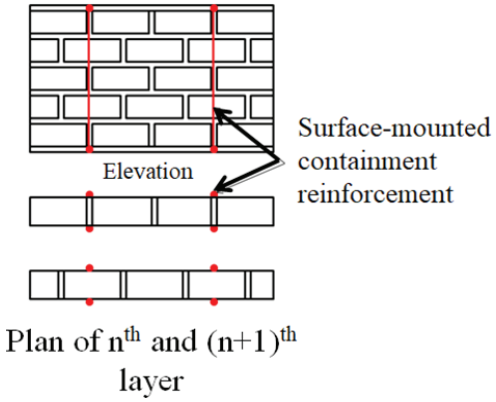

Figure 1. Surface mounted reinforcement

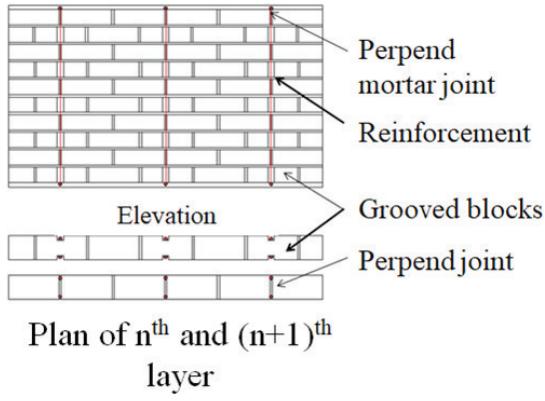

Figure 2. Near surface mounted reinforcement

Raghunath et al., (2012, 2010) and Jagadish et al. (2002) examined the effectiveness of this proposal by conducting flexure tests on masonry beam elements, controlled soft impact tests on reinforced/ unreinforced masonry walls with openings and by shock table tests on 1/6th scale masonry building models with/without containment reinforcement, respectively. In these studies, the containment reinforcement was provided on the surface as shown in Figure 1. Raghunath et al. (2010) demonstrated that the masonry wall reinforced with containment reinforcement, withstood significantly high number of controlled soft impacts without collapsing and sustained almost six times more energy compared with unreinforced masonry wall. Raghunath et al. (2012) achieved a curvature ductility of 10 to 15 with low percentage of containment reinforcement in reinforced masonry beam elements subjected to four point bending. It was emphasized in this work that, the aim of providing the containment reinforcement was not to substantially increase moment of resistance but to impart ductility. Following observations can be made based on the literature on flexural behavior of reinforced masonry; (a) The surface mounted containment reinforcement (Figure 1) poses concerns on durability and (b) The monotonic and reverse cyclic flexure behavior of containment reinforced masonry as shown in Figure 2 has not yet been investigated in past research.

SCOPE AND OBJECTIVES

In the work presented in this paper, behavior of masonry elements reinforced with near surface mounted (NSM) containment steel under monotonic and cyclic, out-of-plane flexure loading has been investigated through displacement controlled four point/three point bending tests. Reinforced masonry elements (hereafter termed as masonry beams) were constructed by employing different bonding arrangements of stabilized earth blocks (SEB) and cement-soil-sand (1:1:6) mortar (viz. stretcher bond, English bond and rattrap bond).

The objectives of study were to (a) study effect of percentage of NSM steel reinforcement on ductility, equivalent hysteretic damping and mode of failure of reinforced masonry beams; (b) comparison of flexure behavior of near surface mounted masonry beams and masonry beams having reinforcement at middepth and (c) evaluate equivalent hysteretic damping and stiffness degradation characteristics of reinforced masonry beams.

EXPERIMENTAL PROGRAM

For the present study, masonry beams with three different bonding arrangements of masonry units and mortar were constructed; (a) stretcher bond masonry beams (depth 110 mm), (b) English bond masonry beams (depth 230 mm) and (c) rat-trap bond masonry beams (depth 230 mm). Rat-trap bond beams were reinforced with the steel reinforcement provided at the center of the pocket formed by bonding arrange- ment of SEBs and cement-soil-sand (1:1:6) mortar. For other beams containment reinforcement was pro- vided as shown in the Figure 2.

Stabilized masonry blocks employed for masonry beam construction exhibited compressive strength of 11.75 MPa, tensile strength of 0.7 MPa and modulus of 6800 MPa. Cement-soil-sand (1:1:6) mortar had compressive strength of 12 MPa and

modulus of 13200 MPa. Galvanized iron (GI) wire, Torkari steel and high yield strength steel employed for reinforcing masonry had yield strengths of 330 MPa, 570 MPa and 520 MPa respectively and ultimate strains of 0.051, 0.011 and 0.055 respectively. The vertical groove accommodating containment reinforcement was later grouted with cement: sand (1:2) mortar.

To rule out the deep beam behavior, span to depth ratio of the masonry beams was maintained well above 2.5 as suggested by Kong (1990). The reinforced masonry beams were reinforced with certain percentage of balanced section steel, as presented in Table 1. The details of the reinforced masonry beams are sum- marized in Table 1. Figure 3 shows the plan of the alternate layers of reinforced masonry beams.

Table1. Details of Reinforced Masonry Beams

		Cross sectional dimensions		Reinforcement details			
Beam designation	Description of beams	B (mm)	D (mm)	Type	Diameter (mm)	Number of bars at top and bottom	% of balance steel
Sb	Stretcher bond	350	110	GI wire	4	2	11.39 (220)#
Eb1	English bond	350	230	GI wire	4	2	2.60 (966)
Eb2	English bond	350	230	Torkari	5.35	2	9.00 (499)
Eb3	English bond	350	230	HYSD	10	2	27.87 (563)
Rtb	Rat-trap bond	390	230	GI wire	4.25	4	28.75 (174)

#values in () is area of balance steel in mm2, B: width of beam, D: total depth of beam

Reinforced masonry beams were cast in vertical position (using following procedure) but tested for flex- ure in horizontal position.

(a) Masonry beams were constructed on the supporting base arrangement consisting of a plywood plank, nailed to three timber legs as shown in the Figure 4 to facilitate shifting of masonry beams from cast- ing yard to testing platform with the use of manually operated forklift.

(b) Base plate was leveled employing the spirit level before construction of beams and a mold made up of wooden planks (Figure 4), having inner dimensions same as cross section of the masonry beam, was fixed symmetrically on the plywood plank. The mold allowed the casting of 50 mm thick base con- crete that held the containment reinforcement of the masonry beams in position.

(c) U-shaped containment reinforcements were positioned inside the wooden mold. Subsequently mold was filled with concrete.

(d) Stabilized earth blocks were soaked in the water for thirty eight minutes (75% saturation time), before they were laid on the mortar layer.

(e) Cement-soil-sand (1:1:6) mortar, with the water cement ratio of 1.43, was prepared in batches and was used for the beam construction by experienced mason. Thickness of the mortar layers was main- tained at about 10 mm throughout the masonry beam constructions.

(f) For rat-trap bond masonry beams, pockets formed in the bonding arrangement of stabilized earth blocks and mortar (Figures 3b and 5a) were filled with the concrete (of similar strength and modulus as that of rat-trap bond prism, with mix proportion of cement-soil-sand-aggregate (1:1:3.5:9) and wa- ter-cement ratio of 1.43) after completion of every four layers of masonry.

(g) GI wire links of 1 mm diameter (ties) were tied to the containment reinforcement as shown in Figure 5c except for the rat-trap bond masonry beams. GI wire links were intended to allow integral behavior of containment reinforcement with masonry and to avoid buckling of the reinforcement on the com- pression face.

(h) Electrical resistance strain gauges were attached to the containment steel in the groove of stabilized earth block close to mid-span of the beam.

(i) Subsequent to placing of last layer of the masonry, containment reinforcements were bent by 90 de- gree with sufficient overlap between the containment steels from two sides of the masonry beam.

(j) Concrete capping of 50 mm thickness was done to accommodate bent reinforcement as shown in Fig- ure 4d.

(k) Concrete projection as shown in Figure 4e provided a leveled surface to rest on support rollers of the bending tests ensuring uniform transfer of support reaction.

(l) Subsequently masonry beams were cured for twenty eight days using wet burlap.

(m) Masonry beams were air dried for at least 10 days at ambient temperature before testing.

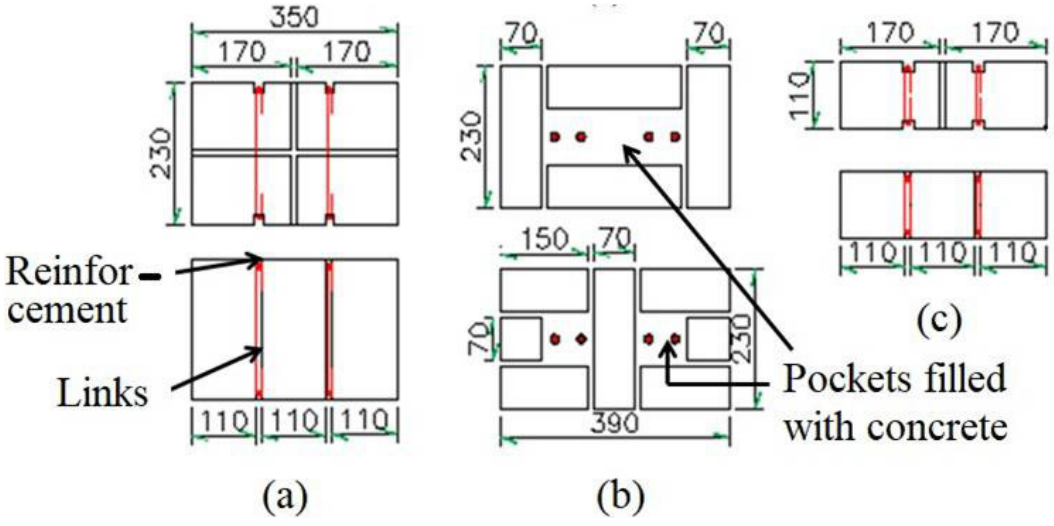

Figure 3. Plan of alternate layers of (a) English bond (b) rat-trap bond (c) stretcher bond beams with containment reinforcement. (all marked dimensions in mm)

TESTING OF THE SPECIMENS

Figure 6a shows view of the experimental setup of monotonic four point bending test. Masonry beams were simply supported on the two rollers at end of the span. Line loads were applied approximately at middle third points with the help of rigid spreader beam driven downwards by servo hydraulic actuator of Material Testing Machine (MTS). Ball and socket arrangement was fitted between loading actuator and spreader beam to ensure verticality of the load. Figure 6b shows view of the experimental setup of reverse cyclic three point bending test. Masonry beams were supported by two rollers at support locations. At support locations, arrangement of top plate and bottom plate which was anchored to base I-section along with top and bottom rollers ensured that the upward and downward reaction would be provided without restraining rotation at the support. Threaded bolts (of 15 mm diameter) were designed to withstand tensile force corresponding to maximum upward reaction. Plates on top and bottom side of masonry beam along with the rollers at loading location were connected to loading actuator of MTS to allow reverse cyclic

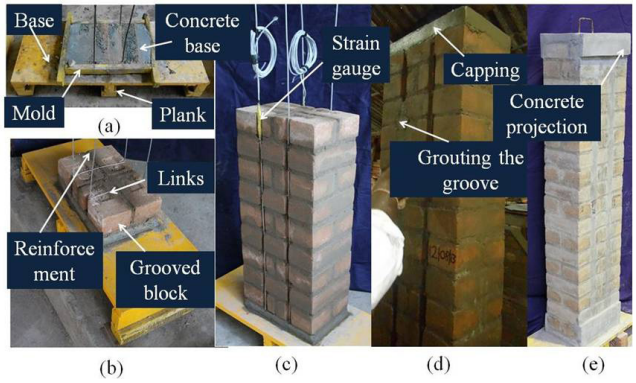

Figure 4. Construction of English bond masonry beam with containment reinforcement

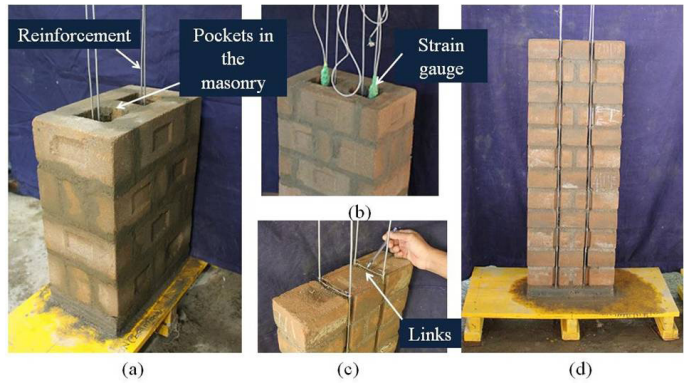

Figure 5. Masonry beam construction, (a) and (b) Rat-trap bond, (c) and (d) Stretcher bond

loading protocol. Following quantities were measured for the masonry beams under monotonic and re- verse cyclic test protocols, (a) load by MTS load actuator on masonry beams; (b) displacement (in the loading direction) at mid-span (monotonic and reverse cyclic test) and at middle third points (monotonic test) of masonry beams; (c) strain in containment steel at or near mid-span of the masonry beam (on com- pression and tension side of bending); (d) strain at top and bottom surface of the masonry beams at or near the mid-span. Table 2 provides more details of the loading, set up and masonry beams. Figure 7 pre- sents a typical displacement pattern (as described in Tomazevic et al., 1996) employed during reverse cyclic tests on reinforced masonry beams. Amplitude of displacement was systematically increased to cover elastic and inelastic range of response.

Table 2. Details of Monotonic and Reverse Cyclic Testing Protocols

Masonry beam des- ignation	Span (m)	Shear span for monotonic test (m)	Span to effective depth ratio	Number of beams tested	
				Monotonic test protocol	Reverse cyclic loading test protocol
Sb	1.47	0.49	15.2	2	2
Eb1, Eb2 and Eb3	1.43	0.48	6.6	2	2
Rtb	1.40	0.47	12.2	2	2

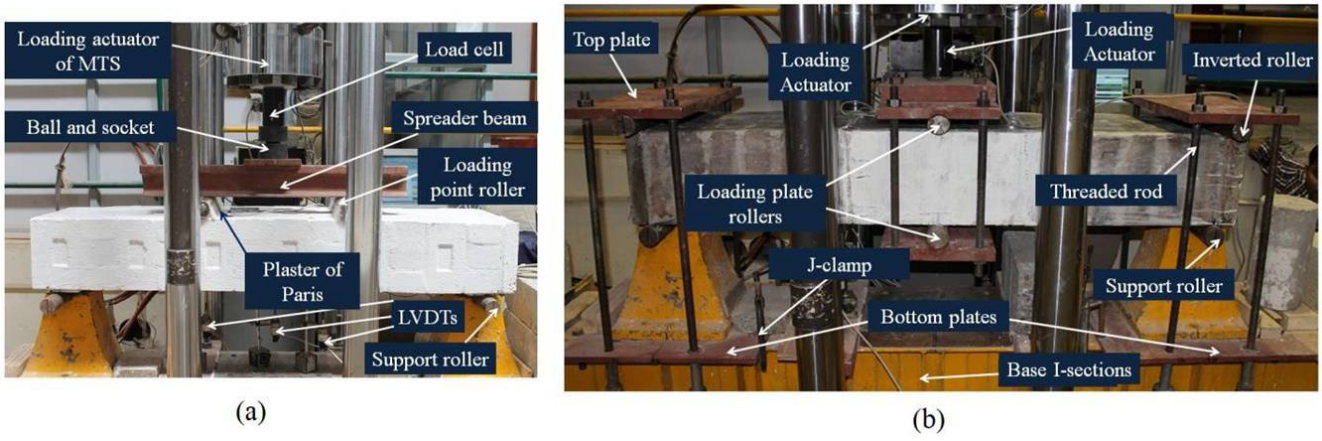

Figure 6. Experimental setup of (a) monotonic bending (b) cyclic bending test of masonry beams

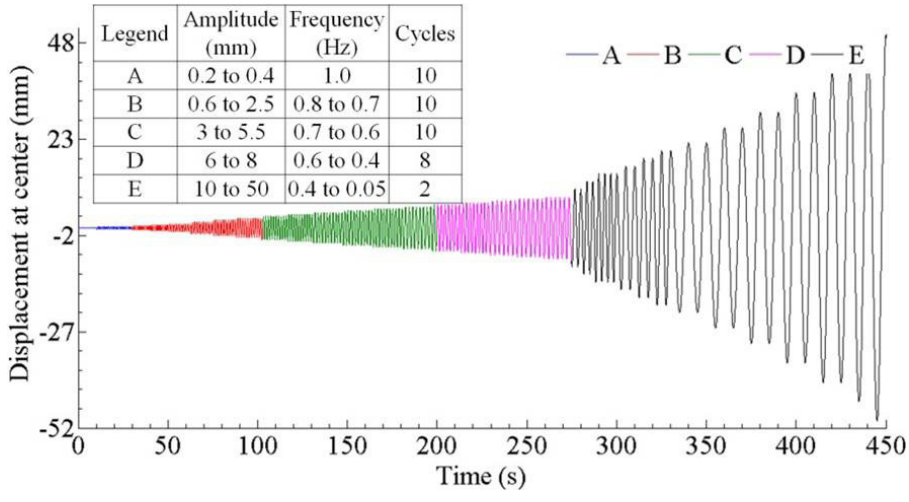

Figure 7. Typical displacement pattern employed for cyclic tests on reinforced masonry beams

RESULTS AND DISCUSSION

Monotonic flexure test

The load-displacement response of reinforced masonry beams allowed monitoring of mid-span displace- ment and corresponding load at following stages, (a) Dcr: mid-span displacement of masonry beam at oc- currence of the first visible crack; (b) Dy: mid-span displacement of masonry beam when the reinforce- ment starts yielding; (c) Du : mid-span displacement of masonry beam at the end of the test (i.e. either when masonry beam collapsed in flexure as for Sb, Eb1, Eb2, and Rtb or when the diagonal shear crack propagated until the top face of the masonry beam Eb3). Curvature of the beam in the pure bending re- gion was calculated using measured strains as

$$\phi = \frac{\varepsilon_t + \varepsilon_c}{d}$$

where, ϕ is the curvature of the beam, ε_t (1)
is strain in the reinforcement on tension side of the beam, □c is strain on the top face of masonry (compression side of bending), d is the effective depth of the beam measured from (top) face of the masonry beam on compression side to center of reinforcement near to bottom face of the masonry beam. The results of monotonic flexure test have been detailed in Table 3.

Table 3. Results Monotonic Flexure Tests on Masonry

Quantity	Beam designation					
	Sp. No	Sb	Eb1	Eb2	Eb3	Rtb
Dcr (mm)	Sp.I Sp.II	0.5 0.6	0.2 0.3	0.4 0.5	0.9 0.6	1.9 1.7
Dy (mm)	Sp.I Sp.II	6.5 6.9	3.3 2.1	5.6 5.3	No yielding	4.1 7.0
Du (mm)	Sp.I Sp.II	65.0 62.5	36.0 26.0	6.3 6.8	19.5 16.7	59.50 59.50
Es (MPa)	Sp.I Sp.II	165 110	127 340	250 350	190 530	90 430
Du/Dy Displacement ductility	Sp.I Sp.II	10.0 9.0	11.0 12.3	1.13 1.28	-	14.5 8.5
□□/□□ Curvature duc- tility	Sp.I Sp.II	7.4 10.4	12.1 7.5	1.3 1.3	-	9.0 9.5

Observations based on these results can be summarized as follows.

(a) Displacement at first crack (Dcr) increased with the increase in amount of reinforcement (e.g. Eb3 showed highest value of Dcr amongst Eb1, Eb2 and Eb3)

(b) The displacement at snapping of steel (Du) of reinforced English bond beams decreased with decrease in ductility of the employed steel (e.g. Eb1 with GI wire reinforcement showed highest Du, whereas Eb2 with Torkari steel showed least value of Du amongst Eb1, Eb2 and Eb3)

(c) Eb3 beam (having 28% of balance section steel) showed flexure-shear failure. The containment steel did not yield as the beam failed in shear before exhausting its flexural capacity. Hence, it is demon- strable that marginal containment reinforcement needs to be provided to improve ductility without switching the mode of failure from flexure to shear.

(d) Displacement ductility of masonry beams was found to be in range 1.13 (Eb2) to about 14.5 (Rtb). Eb2 masonry beam reinforced with Torkari steel, had least value of displacement ductility, as Torkari steel had lowest ultimate strain of all the reinforcing steel employed in this study.

(e) Curvature ductility of masonry beams with containment reinforcement was found to be in range 1.3 (Eb2) to about 12.1 (Eb1)

(f) Though Rtb displayed phenomenal ductility it had poor moment carrying capacity when compared to English bond beam of same depth and similar reinforcement.

Figure 8 shows crack patterns of the reinforced masonry under monotonic four point bending test. Flexur- al cracks were developed in the pure bending zone and were characterized by vertical crack orientation and decreasing widths from tension side to compression side of bending (Figure 8a and c). Reinforced masonry beams except EB3 failed in pure-flexure mode. Flexure crack initiated at the unit- mortar inter- face, on tension side of bending (Sb, Eb1, Eb2, and Rtb). Flexure cracks widened on further loading and beams collapsed due to snapping of containment reinforcement (Figure 8d). Since, the beams were highly under reinforced; crushing of masonry on compression side was not observed.

Masonry beam Eb3 exhibited combined flexure-shear failure (Figure 8b). Pillai and Menon (2003) have given a summary of various types of flexure-shear failures of reinforced concrete beams. The mechanism of failure depends on the ratio of shear span and effective depth of the beam. If this ratio is in between 2.5 to 6, flexure cracks are initiated at early stage of loading and failure in shear occurs by propagation of inclined shear-flexure crack. In absence of shear reinforcement, the failure occurs suddenly and termed as diagonal tension failure. The ratio of shear span to effective depth of Eb3 was 2.17 (close to 2.5). Eb3 exhibited pure-flexure crack and on subsequent loading (at load about 28 kN), shear crack initiated in the shear span of the masonry beam. The failure of Eb3 occurred in diagonal tension mode as shown in Fig- ure 8b. It can be attributed to substantial enhancement in flexural strength (due to high percentage of steel) without shear strengthening.

Figure 8. Failure pattern of the (a) EB1 (b) EB3 (c) Rtb and (d) snapping of steel

Cyclic flexure test

Figure 9 shows the load-displacement hysteretic behavior of reinforced masonry beams subjected to cy- clic loading. It is used to evaluate; (a) equivalent hysteretic damping and, (b) stiffness degradation due to cyclic loading. Equivalent hysteretic damping and stiffness degradation are calculated at various dis- placements using the following expressions given by Priestley et.al. (2007) and are plotted in Figure 11 and Figure 12.

$\xi_{eq} = \xi_e + \xi_h$; where, ξ_{eq} is the equivalent damping ratio, ξ_e is the elastic damping ratio

and ξ_h is the hysteretic damping ratio. Normalized displacement was obtained by taking ratio of instanta- neous mid-span displacement to magnitude of maximum mid-span displacement in cyclic three point bending test of the reinforced masonry beams. Equivalent hysteretic damping at a particular displacement is proportional to area enclosed in complete hysteresis loop at that displacement and is obtained using the equation;

$$\xi_h = \frac{Ah}{2\pi F_m D_m}$$; where, A is area of hysteresis loop at maximum displacement D and load F

as shown in Figure 10 (Priestley et. al. 2007).

Figure 11 presents variation of hysteretic damping of masonry beams with normalized displacement. Hys- teretic damping (of masonry beams reinforced with steel reinforcement) at 100% normalized displace- ment varied from 5% for Eb2 to 20 % for Eb1. Eb2 was reinforced with Torkari steel having least ductili- ty amongst all other steels, which was reflected as having least value of hysteretic damping. On the other hand GI wire showed most ductile behavior under uniaxial tension, consequently, Eb1 had the highest hysteretic damping at 100% normalized displacement. Figure 12 presents degradation of stiffness of ma- sonry beams with normalized displacements. Sb, Eb1 and Rtb showed sharp decrease in initial stiffness at small value of normalized displacement, indicating prevalence of large yielding strains. The remaining reinforced masonry beams, on the other hand, showed stiffness degradation at slow rate with increasing normalized displacement indicating more brittle behavior and sudden collapse without warning.

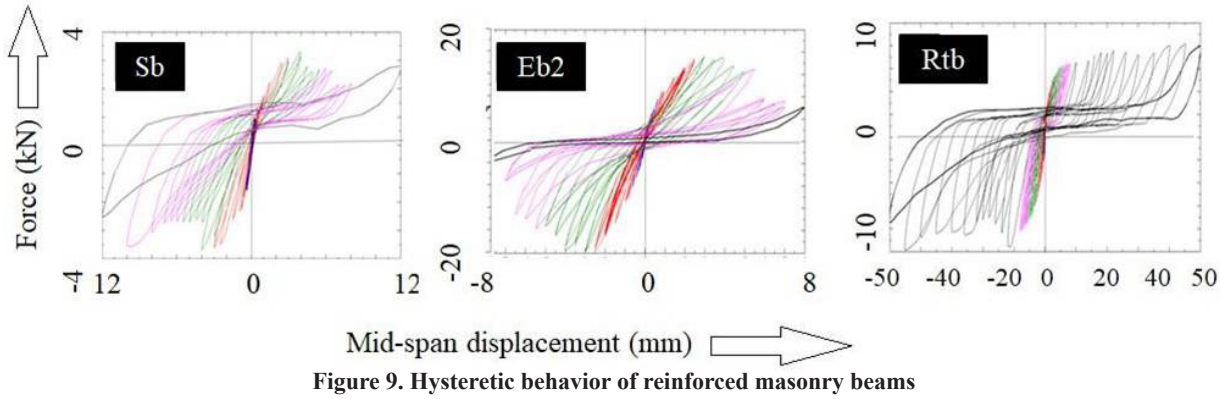

Figure 9. Hysteretic behavior of reinforced masonry beams

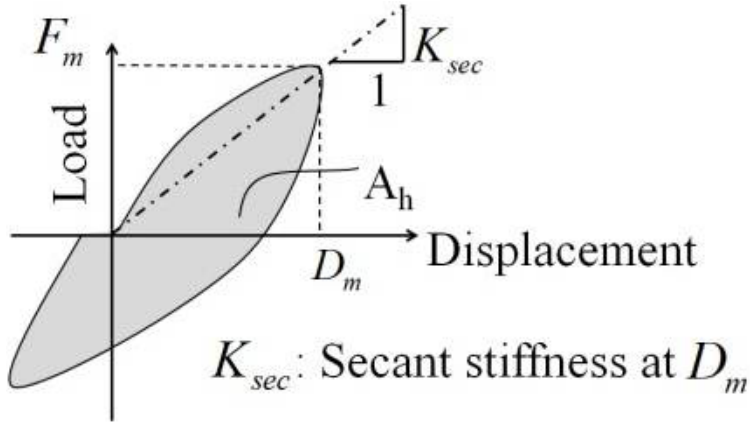

Figure 10. Details of load-displacement hysteresis loop

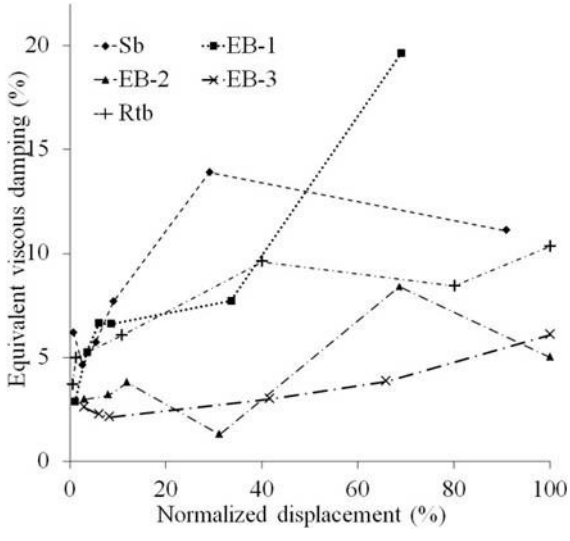

Figure 11. Equivalent hysteretic damping

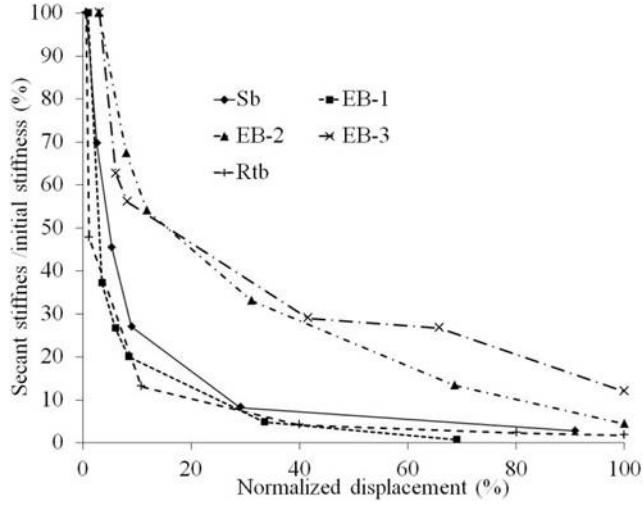

Figure 12. Stiffness degradation of reinforced masonry

CONCLUSIONS

Based on the investigations conducted the following conclusions can be drawn;

1. By modestly reinforcing masonry it is possible to inhibit brittle failures and impart ductility and ener- gy dissipation capacity.
2. Near surface mounted reinforcement imparts greater strength and ductility to masonry than rein- forcement provided at mid-depth as in case of rat-trap bond masonry beams.
3. The masonry beams reinforced with containment steel, did not show buckling of steel on compression side of bending, affirming the effectiveness of lateral ties provided through bed joints to hold the con- tainment steel.
4. Provision of containment reinforcement shall be aimed at improving ductility and not for increasing moment of resistance. Provision of excess steel can modify the mode of failure from flexure to shear rendering poor ductility and brittle collapse.

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Recycling of Construction Demolition Waste

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1. Introduction

India is one of the fastest growing economy and is urbanizing rapidly. Over the next 30 years, 53% of the population is expected to be in urban agglomerations. According to the guidelines issued by Ministry of Urban Development (2015), about 303.5 million sq.m. of real estate, covering 25,000 acres of land will need greenfield development and additional 202.3 million sq.m of existing buildings will need to be redeveloped. Prime examples of greenfield development are cities such as Amravati, the proposed new capital of Andhra Pradesh, while the Saifee Burhani Upliftment Project in Mumbai and East Kidwai Nagar in New Delhi are examples of large redevelopment projects.

Construction of infrastructure, particularly in developing countries, is associated with positive externalities, such as livelihood generation and hence desirable. However, rapid growth, particularly unplanned activity, is often associated with increased pollution loads. According to a report by IQAir AirVisual (2019), Indian cities rank amongst the most polluted, with six featuring in the list of top ten. For example, the concentration of Suspended Particulate Matter (SPM) in large metros such as Delhi, Mumbai is routinely in the "Unhealthy" category (100-150) and in "Very Unhealthy" in winter months. One key reason for increasing pollution is the lack of facilities for scientific waste management and capturing of pollutants.

Even though C&D waste is the largest components of the waste stream, it was traditionally ignored. There were several reasons, such as its relatively inert nature, possibility of utilization in refiling and less benign options such as illegal dumping in water bodies or by roadsides. Due to lack of focus, the estimates of total C&D waste generated at city level and across the country are unreliable and vary from 15 million tons to 625 million tons per year (BMTPC, 2018).

The health cost of the pollution has attracted increasing attention of the regulators, judiciary and common man in the recent years. As a result, policy and pragmatic action has gained momentum. Several steps have been initiated such as amendments to the Waste Management Rules in 2016, stricter norms for power plants, launch of new initiatives such as the Swachh Bharat Abhiyaan (Clean India Program), the Namami Gange Program (National Mission for Clean Ganga), amongst others.

2. C&D Waste Management Rules and Implementation Status

2.1. Need for amendment to the waste management rules

The need to scientifically manage C&D waste was first recognized in the Municipal Solid Waste Rules 2000, but with insufficient details i.e. it did not include relevant details, particularly roles and responsibilities as well as lack of incentives and penalties. As a result, they proved inadequate to the challenge. Over the last two decades, lack of C&D waste management facilities appears to have contributed significantly to the environmental damage in various forms. For example, C&D waste dumped along roadsides leads to increased SPM as it tends to degrade over time. Metro cities such as National Capital Region, a centre of construction activity over the last two decades has witnessed increasing level of PM 2.5 concentration in recent years. In some years it crosses 150 µg/m3 in the summer while in the winter it was found to be around 200µg/m3, against the acceptable level of 60 µg/m3. According IIT Kanpur (2016) study, construction and demolition waste combined with batching activities were consistently amongst the largest contributors to the pollution load. Chemicals from dumped debris often leach into the land, particularly during the monsoons, causing land degradation and contamination of ground water. A significant portion of C&D waste tends to be dumped in water channels, natural and manmade drains, leading to clogging and flash floods. Mumbai and Chennai are prime witnesses. According to CAG (Citizen Consumer and Civic Action Group) (2016) study, one of the contributing factors for Chennai floods in 2015 was the mismanagement of C&D waste. Increasing pressure from judiciary, think-tanks and citizen groups created momentum for enactment of C&D Wate Management Rules in 2016.

2.2. C&D Waste Management Rules, 2016

Given the increasing pollution load, consequent economic and health costs, a more comprehensive and separate set of regulations for managing various types of waste were enacted in early 2016. These included the Construction and Demolition Waste Management Rules (2016) (in brief C&D Rules 2016), Solid Waste Management Rules (2016), Plastic Waste Management Rules (2016) and E-Waste Management Rules (2016).

These rules embodied several common principles creating an enabling, consistent, and supportive framework for implementation by Urban Local Bodies (ULB). Five most important are outlined here. The first principle emphasized source segregation, in-order to increase recycling and reuse opportunities. A complementary provision, mandating the usage of recovered materials was the second key principle. In case of Municipal Solid Waste (MSW), for example, the rule requires all industrial units within 100 km radius to replace 5% of the fuel requirement with Refuse Derived Fuel. Likewise, the C&D Rules require public construction projects to use 10% to 20% recycled materials. Third, the rules clearly outline the duties of the waste generators,

with emphasis on the concept of extended producer responsibility. This approach strengthens the "polluter pays" principle, already enshrined in various orders, by levying and or increasing the fees to be paid by the generators. Fourth, the rules outline the responsibility of various arms of the Government, such as policies to be issued by the State Governments, guidelines to be prepared by the Pollution Control Boards and specific provisions for local authorities such as ensuring availability of land. Last, but not the least, the rules prescribe a timeline for various milestones, most notably for operationalising waste processing facilities. Table-1 below illustrates key provisions of the C&D Rules 2016 in so far as roles and responsibilities of various stakeholders and timelines for key milestones are concerned.

Provision under the Rules	City with Population		
	1 Million +	0.5-1.0 Million	< 0.5 Million
State Government: Formulation of the C&D waste management policy	12 months	12 months	12 months
Local Authority: Identification of sites for collection and processing facility	18 months	18 months	18 months
Local Authority: Commissioning of the Processing facility	18 months	24 months	36 months
State Pollution Control Boards: Approvals, Monitoring and Reporting	3 times/year	2 times/year	2 times/year
Central Pollution Control Board: Environmental Management Guidelines and Annual Report	Once a Year		

Table 1: Key provisions and timelines under the C&D rules 2016

Source: Ministry of Environment, Forest and Climate Change, C&D Management Rules, 2016

2.3. Complementary regulatory provisions

In addition to the C&D Rules 2016, two complementary regulatory provisions were enacted to C&D Rules 2016. Both relate to the standards for enabling use of recycled materials for various purposes. The Bureau of Indian Standards amended the specification IS 383:2016 for coarse and fine aggregate for concrete (3rd revision) in 2016. The revised specification includes manufactured aggregates produced from other than natural sources for use in the production of concrete for normal structural purposes, including mass concrete works. The revised IS 383: 2016 thus allows use of up to 20% recycled concrete aggregates in Reinforced Concrete (M 25 grade) as coarse or fine aggregate and up to 100% in Lean Concrete (< M 15grade). This modification is consistent with provisions of the National Buildings Code (NBC-CED 46) of India 2005: Part 11 which allows up to 30% replacement of natural aggregates with recycled concrete aggregates.

2.4. Results: Assessment of the implementation status

According to the C&D rules 2016, State Pollution Control Boards (SPCBs) should submit reports to Central Pollution Control Board (CPCB) regarding the status and the waste generation data. However, no information is readily available in the public domain. A report by the Niti Aayog, the Government's think tank, (Strategy for Promoting Processing of Construction and Demolition (C&D) Waste and Utilisation of Recycled Products) dated 5 November 2018 suggests that only two out of fifty-three cities with million plus population have operational facilities. This appears to be somewhat dated information. Available information based on extensive review, triangulating information from multiple sources indicate that the progress till date has been slow, with only six out of thirty-six states and UTs, i.e., about 17%, having either issued a policy or a draft version of the policy for managing C&D waste. The situation is similar at the city level, with only six out of forty-four cities i.e., 15%, having issued bylaws for C&D waste management. Nine out of forty-four i.e., 20% had an operational facility and another ten i.e., less than 25% were in the process of constructing one. Contrast this with the requirement under the C&D Rules 2016 that all cities need to have an operating facility by March 2019. Since there is no information available on most of the other cities, overall compliance to the C&D Rules 2016 may be less than 10%, given that there are about 300 cities with a population of 100,000 and above. There are several reasons for slow progress which we discuss in following sections, along with policy and business enablers required to advance scientific management of C&D waste.

3. Systematic Assessment of C&D Waste

One of the key bottlenecks in planning and operationalizing C&D waste management facilities relates to the lack of data, quantitative and qualitative. In the absence of data, most ULBs are unable to arrive at proper estimate of the scale, type and logistics required to implement the mandate under the C&D Rules 2016. The Ministry of Environment, Forests and Climate Change (MoEF&CC) and related government agencies such as the Central Pollution Control Board acknowledge that there is no systematic database or reliable estimate of C&D waste in India.

3.1. Widely Varying Estimates of C&D waste

Various estimates have been derived by various agencies, official and independent, at different points in time. Data in the table highlights the dilemma in planning and implementing scientific C&D waste management, considering that the difference

between the minimum and maximum estimate is over 5000 percent. The situation at the city and town level is even worse, as in most cases, there is simply nothing available.

Name of the Agency	Estimation Year	C&D waste (Million MT /annum)
Ministry of Environment & Forest (MoEF&CC)	2010	10-12
Technology Information, Forecasting and Assessment council (TIFAC)	2001	12-15
Central Pollution Control Board (CPCB)	2017	12
Building Material Promotion Council (BMTC)	2013	165-175
Centre for Science and Environment (CSE)*	2014	530

Table 2: Estimates of quantity of C&D waste from various agencies

Source: CPCB – March 2017 *CSE Report No:3- 2014

As evident, it is likely that some of the numbers, particularly from the Government agencies above, may be an underestimate of the overall C&D waste quantum. Further, there is a lack of clarity on the methodology adopted by different agencies. To illustrate, CSE used TIFAC guidelines on the amount of waste generated per m2 of construction (40-60 kg per m2), demolition (400-600 kg per m2). and repair (40-60 kg per m2), to arrive at the quantity of waste from construction (50 million tons), demolition (288 million tons) and repair (193 million tons), respectively in 2013, i.e. collectively a total quantity of 530 million tons. On the other hand, TIFAC's own estimate for 2001 was much smaller i.e. 12-15 MT. Obviously, the rather large difference cannot be explained by the fact that the two estimates were 12 years apart.

Another aspect worth highlighting is the fact that the CSE estimate is based entirely on buildings constructed. Hence, it appears, that waste from construction of infrastructure projects such as highways and from the Ready Mixed Concrete plants is not included. Given the scale of large infrastructure projects and 60 million-meter-cube of RMC produced annually, the possibility that CSE may have also underestimated cannot be ruled out. The more important point being the need for a transparent and objective assessment of the quantity of waste. At city or town level, another detail which is required for planning and design is the characterisation of the waste in terms of its constituents. The available data on the constituents of C&D waste in India is in Table 3 below.

Constituent	TIFAC Estimate (2001)	MCD Survey* Estimate (2004)	BMTPC#
Estimate (2018)			
Soil/Sand, Gravel	36	43	26
Bitumen	2		
Metal	5		6
Masonry/Bricks	31	35	32
Concrete	23	35	28
Wood	2		3
Others	1	7	5
Total	100	100	100

Table 3: Estimate of constituents of C&D waste from various agencies (%)

Source: *ICI Guidelines 2013 # BMTPC Ready Reckoner Oct 2018

The TIFAC estimate in Table 3 are average numbers for the country whereas the MCD (Municipal Corporation of Delhi) estimate is for Delhi and the BMTPC estimate is for urban areas in North India. The absence of data on characterization of waste is often a barrier in designing an optimum plant and strategy. It leads to multiple distortions, depending on the context. For example, lack of interest by bidders in the tendering process, higher prices due to increased risk perception and inability to operate or a costly renovation, after the plant has been operationalized.

With the above backdrop, a systematic assessment of C&D waste generated in Goa was developed by the SINTEF team comprising of the author as part of work under the C&D WIN project.

3.2. C&D-WIN project:

SINTEF AS, an independent research organisation based out of Norway is supporting Indian organizations under a program funded by the Royal Norwegian Embassy. This program, titled "Treatment and recycling of construction and demolition waste in India (C&D-WIN)" enables joint activities to provide assistance to CPWD, Urban Local Bodies and private sector entities

in India towards safe, scientific treatment and utilisation of C&D waste.

As a part of the C&D-WIN activities, SINTEF and Goa Waste Management Corporation (GWMC) entered into a MoU to focus on C&D waste management. The aspiration of Goa is to develop, operate and maintain a world class C&D waste management facility towards the principle of circular economy, to enhance environment sustainability of its sensitive ecosystem. The overall objective of the Project is to implement safe, scientific treatment and utilisation of C&D waste in Goa.

3.3. Methodology and Process for Systematic assessment of C&D waste in Goa:

As with the rest of the country, neither the urban local bodies in Goa nor the State Pollution Control Board (GPCB) had readily available authentic data on the volume or the composition of the C&D waste generated in Goa Therefore, after deliberations with stakeholders, it was agreed that the best possible method to estimate the volume and stream of waste generation from C&D activities was to derive the same from the three main streams of C&D waste. These three streams included construction activity, demolition activity and refurbishment of hotel rooms, a large sector requiring frequent renovation and hence significant contributor to overall C&D waste in Goa.

As a starting point in the data collection drive, more than 40 key stakeholders of the Goa construction industry were identified, and meetings conducted. This included three ULBs, the planning departments (TCP and Planning and Development Authority – North and South Goa), various Government development agencies such as Goa Industrial Development Corporation (GIDC), Goa Tourism Development Corp, Goa State Infrastructure Development Corporation, Goa Public Works Department, Goa Pollution Control Board, Indian Navy-Western command, Leading engineering contractors such as Larsen and Toubro and Dilip Buildcon Ltd, real estate developers such as Adwalpalkar constructions and Nanu group of companies, architects such as Devari and associates and Effective architectural solutions key players in the hotel industry Taj group of hotels and Novotel, Building material suppliers such as Cement companies, RMC suppliers, Concrete pavers and blocks manufacturers and suppliers of vitrified and ceramic tiles, demolition contractors and debris transporters.

Detailed discussions with key individuals and organisations provided an understanding of the construction market of Goa, type of building materials used and construction practices in urban and rural areas of Goa, the current and the potential areas for future growth, the demolition methods and disposal means for the debris. The location of the RMC and precast companies and the waste generated at the plant and supply site was mapped to identify the volume and the geographical distribution of the waste. A detailed list of all hotel units in Goa, with their location, from the single room facilities to the large 500 room hotels was collected and their cycle of refurbishment studied, along with the composition of the waste generated per square metre of refurbishment. Builders, architects and contractors were consulted to obtain an accurate estimate of the average waste generated in the construction phase of different building materials, from concrete and blocks to plumbing materials, electrical cables, packing materials, bathroom fittings and accessories. The discussions with the demolition contractors and the debris transporters provided critical inputs on the demolition process, composition of the debris, the peak season for demolition activities, transportation and disposal means adopted, including prices charged.

3.4. Results and Key Findings

As mentioned above, the methodology adopted for estimation of waste was to analyse three separate streams i.e. construction, demolition and hotel renovation, to arrive at the overall waste quantity and its likely composition.

3.4.1. Waste from construction activity

The starting point for this stream was the data from Town and Country Planning (TCP) Department, which levies a one-time tax on all construction projects with a size exceeding 100 square metres. This data was collected along with similar data for the industrial buildings from GIDC. The data was classified under residential, commercial, and industrial categories for analysis purposes, as materials used vary by the type of structure. The data was also segregated on geographic basis i.e. by each of the twelve Talukas in the state.

In addition to the waste generated at the site during construction, waste is also generated in the supply chain of the Ready Mixed Concrete (RMC) industry, an essential input to most large structures. Goa has an annual production of 330,000 m3 of concrete, from thirteen plants located in the state. On an average, the waste generated in these plants is approximately 1.5 to 2 percent of the total production. This includes the spilled concrete during batching, rejects due to technical, placement, and workability related issues, crushed concrete cubes used for testing, chipped off concrete from the build up inside the plant mixer and truck mixer. This waste was estimated to be 32 MT/day based on the current production volume and mapped to each Taluka, based on the geographic location of each plant.

Based on the estimate of waste generated during the construction phase for different categories, and aggregating the waste generated from the RMC plants, the total waste generated from construction activity was estimated to be 266 MT per day. Its composition for each Taluka is presented in Table 4 below.

Location	Concrete	Concrete blocks	Laterite stones	Tiles/ Granite	Aerated concrete	Paver block	Cement Mortar	PoP/ Gypsum	Other	Total
Tiswadi	8.9	14.5	5.3	3.2	5	1.6	6.7	0.5	0.4	46
Bardez	27.3	27.4	8.6	6.4	10.8	3	12.2	0.9	0.7	97.3
Salcete	9.8	9.6	13.2	2.7	4.6	1.4	5.5	0.3	0.3	47.5
Marmugao	13.7	2.7	0.5	0.3	0.6	0.8	1	0.1	0.1	19.7
Ponda	9.6	4.1	1.7	0.6	0.8	0.6	1.7	0.1	0.1	19.3
Pernem	0.5	0.6	1	0.1	0.1	0.1	0.4	0.02	0.02	3
Bicholim	4.3	2	1.7	0.5	0.6	0.2	1.4	0.1	0.1	10.8
Sattari	0.4	0.2	0.5	0.1	0	0	0.2	0.01	0.01	1.4
Quepem	2.5	1.7	3.2	0.6	0.2	0.2	1.5	0.1	0.1	10.2
Sanguem	1.7	0.5	0.4	0	0	0	0.3	0.01	0.01	3
Dharbandora	0.1	0	0.1	0	0	0	0	0	0	0.2
Canacona	2.6	1.3	1.9	0.6	0.4	0.1	1.1	0.1	0.04	8.1
Total	81.5	64.6	38.2	15.2	23	8.1	32.1	2.1	1.7	266

Table 4: Construction waste volume and its composition (Taluka-wise, MT per day)

Source: Author's calculations

3.4.2. Waste from demolition activity

Majority of the demolition activity in Goa is directly linked to the tourism industry which is located along the coast. Within the demolition, waste from hotel refurbishment was estimated separately and is presented in the next sub-section. The peak of the demolition activity, during which about two-thirds of the waste generated, occurs between June and September, coinciding with the monsoon off-peak season for tourism. There was limited evidence of systematic de-construction being adopted during demolition of buildings. In most cases, the demolition was carried out using an excavator, the resultant waste being a mixture of concrete, mud, laterite, and gypsum. There are two main types of buildings demolished in Goa viz. the Mangalore roof tiled buildings and the concrete roofed ones. The Mangalore tiles themselves however do not form a significant part of the waste stream as they are salvaged and removed before demolition. Table 7 below summarises the volume of waste per square metre of demolition and the typical composition of the waste in percentage.

Type of Construction	Average MT/ m2	Laterite / Mud	Concrete	Mortar	Tiles and Bathroom fittings	Gypsum / PoP
Mangalore Tile Roofed	1.6	65%	3%	24%	5%	3%
Concrete Roofed	2	52%	20%	21%	4%	3%

Table 5: Composition of the C&D waste from demolition of different type of structures

Source: Based on anecdotal evidence collected from demolition contractors and debris transporters in Goa.

Total waste generated from demolition activities, other than hotel refurbishments, was estimated to be 250 MT per day. Table 8 below summarises the Taluka-wise waste generated from demolition in different parts of the state along with its composition during a typical year.

Taluka	Major Town/City	Laterite / Bricks	Mortar	Concrete	Ceramic/ Tiles	Gypsum	Total in MT/ Day
Bardez	Calangute, Candolim	37.7	14.3	7.8	3.2	2	65
Tiswadi	Panjim	43.5	16.5	9	3.8	2.3	75
Marmugao	Vasco	31.9	12.1	6.6	2.8	1.7	55
Salcete	Madgao	31.9	12.1	6.6	2.8	1.7	55
Total		145	55	30	12.5	7.5	250
% of Total		58	22	12	5	3	

Table 6: Demolition waste volume and its composition (Taluka-wise, MT per day)

Source: Author's calculations

3.4.3. Waste generated from refurbishment of hotel rooms

There are 1686 hotel units in Goa with 30,720 rooms. The franchise of global chains typically undertakes mandatory renovation every 5-7-years, where all rooms in a hotel are refurbished. On the other hand, large Indian chains, such as the Taj Group, which are more conservative and maybe have better maintenance practices, typically manage to extend the refurbishment cycle to 8-10 years. In case of small units, refurbishment of rooms is usually linked to ownership change. A standard hotel room typically generates 1 MT of waste during refurbishment. The waste composition is fifty percent cement mortar, twenty two percent ceramic tiles, bathroom fittings and remaining twenty eight percent Gypsum. For this estimation, an annual volume of waste from refurbishments of hotel rooms, a period of 7 years was assumed on a linear scale of generation. The total volume of waste thus calculated from refurbishments to be approximately 10 MT per day and its composition is presented in Table7 below.

Waste type	Daily Generation
Cement Mortar	5.00
Tiles and Bathroom accessories	2.30
Gypsum board and Plaster of Paris	2.85
Total	10.15

Table 7: Refurbishment waste volume and its composition (MT per day)

Source: Author's calculations

3.4.4. Total C&D waste and its composition

Based on the above three streams, the total volume of C&D waste generated in Goa was arrived at to be 266 MT/day, 250 MT/day and 10 MT/day, respectively from construction, demolition and hotel refurbishment activity, collectively adding to appropriately 525 MT/day. Construction practices specific to Goa were carefully considered while estimating the waste volume and its composition. For example, while bricks constitute a major share of the waste composition in many parts of the country, it is rarely used in Goa, laterite stones being the most preferred option, followed by concrete blocks. Ceramic tiles and bathroom fittings constitute a considerable share of the waste stream in Goa as different from other parts of the country, which is due to many hotels undertaking frequent renovation. This information provides a practical input to the recycling agency for designing the plant and more importantly for identifying recycling opportunities after treatment. The excavated soil was generally used at the site itself for back-filling and for practical purposes not included as its quantity was insignificant. The overall waste composition for Goa is presented in Table 8 below.

Material	Waste Generated	Proportion
	(MT per day)	(% of the total)
Concrete	110	21
Concrete blocks + Pavers	95	18
Cement Mortar	90	17
Laterite stone / Mud	185	35
Tiles	30	5.7
Gypsum / PoP	13	2.5
Others	2	0.3
Total	525	100

Table 8: Composition of C&D Waste in Goa

Source: Author's calculations

This ground-up approach provides a detailed understanding of the waste generation and is significantly better for making informed decisions. To illustrate, the waste generated is estimated Taluka-wise, thereby providing a critical input for siting the recycling facility and transfer stations, thereby ensuring optimization of transportation. Further, understanding of the waste stream generated during construction and key development zones is a key input for the source segregation strategy.

Based on the future re-development plans, the composition of waste arising from the demolition activity can be analysed using the above approach. Overall, treatment and recycling projects can benefit significantly by adopting a scientific approach to assess the quantity and composition of the C&D waste. It is however pertinent to note the dynamic nature of the construction, demolition industry and consequent flexibility required to incorporate new strategies and approaches.

4. Recycling Opportunities in the Construction Industry

Construction is expanding rapidly in the country. For example, the Building Materials and Technology Promotion Council (2018) estimates that in the current year, India will require 380 Million MT of cement, 400 million cubic metres of aggregates and 600 billion bricks. Courts and regulators have been forced to take a stand against illegal mining, common in many parts of the country. As a result, river sand as fine aggregates have been banned from construction and so is the use of kiln bricks due to the over-use of topsoil. Sources of natural aggregates, especially those in proximity of major cities, sites of major construction activities, are depleting fast. Anecdotal evidence suggests that this has resulted in significant increase of the average distance of transporting these materials, maybe as much as 50% in some cases over the last decade. Thus, traditional building materials are increasingly scarce, costlier and therefore the need to think about sustainable solutions to meet the increasing demand.

Annually, 40 billion MT of aggregates are extracted globally, making it the second largest extracted resource in the world. To put this into perspective, the aggregates extracted annually is 9 times that of crude oil. Sand and aggregates, once considered an unlimited resource not very long ago, are depleting rapidly. Hence, countries across the globe have focussed on recycling C&D waste to use them as aggregates in construction. The recycled products are generally classified into two types, Recycled Concrete Aggregates (RCA) which is predominantly product of demolished concrete and Recycled Aggregates (RA), which is predominantly demolished concrete which may include masonry and asphalt.

According to the European standard EN 206:2013, up to 50% replacement of natural coarse aggregates by recycled concrete aggregates in concrete is possible, depending on the characteristics of the RCA and the environmental class for the concrete (ICJ Jan 2020). International evidence suggests that across the globe, many countries have made progress in the use of recycled materials in construction (ICI -2013). In Norway, the Sorumsand High School project, completed in 2003, half of the concrete used in the building was from recycled aggregates and 37 percent of the natural coarse aggregates were replaced by recycled concrete aggregates. The project was implemented as a demonstration project in collaboration with the local county authority (ICJ Sep 2019).

Germany has also made considerable progress in advancing the use of recycled materials. Through a combination of high landfill charges, widespread use of recycled aggregates in roads and parking lots and preferential procurement of recycled products by local authorities, the recovery rate in Germany is now approximately 95 percent. The market for recycled concrete in Germany is primarily in road construction as lays and drainage material. DIN 1045 permits up to 25% RCA in structural concrete of cube strength 37.5 MPa in dry or low humidity environments.

In the United States, regulatory issues vary from state to state, but the major use of recycled concrete aggregates is in road sub-base. Up to 100% replacement of coarse aggregate is allowed in all non-structural concrete up to 20MPa. For structural applications, ASTM C94/C94-11 b 55, allows replacement of 20-25 percent of coarse aggregates in higher grades of concrete.

In the United Kingdom, use of RCA does not have strength limitation for concrete, provided there is no contamination. For cube strengths of 25 to 50 MPa, a maximum of 20 percent replacement of coarse aggregates is permitted in designated concrete. RA is for unreinforced concrete limited to strength of 20 MPa. According to the European aggregates association, UEPG, most of recycled aggregates find their uses as base layer materials in road and infrastructure works, representing up to 20% of the total of this demand in Europe (ICJ Sep 2019). Many leading countries such as Japan, Australia, South Korea also have similar guidelines that encourage use of aggregates from recycling of C&D waste in concrete, both structural and non-structural.

In India, as mentioned earlier, the Bureau of Indian Standards amended the Indian Standards for Aggregates in Concrete (IS 383) in 2016 to allow use of upto 20% recycled concrete aggregates in Reinforced Concrete (M 25 grade) as coarse or fine aggregate and upto 100% in Lean Concrete (< M 15grade). The standards classify the recycled aggregates into two categories i.e. Recycled Concrete Aggregates (RCA) and Recycled Aggregates (RA). This is a welcome development that will provide the necessary impetus for the Indian construction industry to use recycled products from C&D wastes in both structural and non-structural works. There is a viewpoint that the replacement limits can be enhanced without compromising the quality of concrete, but the current limits suggested in IS 383 should be viewed more as a starting point. Given that it is rare to find buildings using even the current limits and therefore limited data on actual experience, it is difficult to make a case for enhancing limits without necessary evidence. The onus is thus on the construction industry to embrace this opportunity to develop templates and necessary confidence to convince the BIS Committee for enhancing upper limit for use of recycled concrete aggregates. For developing the required confidence and garnering support, the industry needs to demonstrate continuous use of recycled aggregates, documentation of data and verifiable results on a continuous basis, over a period. In addition, work on addressing consumer confidence, mindset issues and environmental sensitization will also facilitate and enable a case for higher limits

In the current scenario, recycled aggregates, both fine and coarse, can be effectively used in multiple applications such as:

4.1. Concrete

BIS permits the use of RCA as both coarse and fine aggregates up to 20% in reinforced concrete in grades up to M25 and up to 25% replacement in plain concrete. Further, it allows 100% use of both RCA and RA in lean concrete below M15 though RA is permitted only in the form of coarse aggregate. This is a major step in promoting the use of recycled aggregates in

concrete. Although use in higher grades is currently not permissible, it must be noted that more than 50% of the concrete made in the country is grade M25 and below. Hence there is significant potential for using recycled aggregates within the current regulations. To further encourage and enhance use of RCA in concrete, it is important to test the properties of RCA. Compared to natural aggregates, the water absorption values of RCA are typically higher and exhibits greater variability. This is due to the presence of hydrated cement paste in the RCA. There is a resultant decrease in the specific gravity and increased porosity leading to higher water absorption. Both these properties (specific gravity and water absorption) have an impact on the concrete behaviour and therefore, the mix design has to be suitably modified while using RCA. Other characteristics that need to be monitored are the permissible values for free chlorides and sulphate. Thus, a proper testing regime, preferably through a third-party testing agency needs to be implemented to enhance transparency and confidence of all market players.

4.2. Precast Concrete Products

One of the most common and effective use of recycled aggregates is in the pre-cast concrete industry, especially for the concrete blocks, bricks and pavers. As mentioned previously, India will require an estimated 600 billion number of concrete blocks and bricks annually. Since these applications are non-structural in nature, recycled aggregates can completely replace natural aggregates. Many existing C&D processing plants also have concrete blocks and paver manufacturing activities co-existing to manufacture value-added products ensuring seamless consumption of the recycled aggregates. Other pre-cast products that can be produced are concrete floor and wall tiles, kerb stones, concrete fence posts, drain covers, garden furniture, benches and a host of related concrete products.

4.3. Granular Sub-Base for Roads

Recycled aggregates are an excellent replacement for natural aggregates in the construction of sub-base for roads. The crushing characteristics of hardened concrete are similar to natural rock and are not significantly affected by the grade or quality of the original concrete. Recycled concrete aggregates produced from original concrete can be expected to pass the same tests required of conventional aggregates. RCA can be used in granular sub-base and lean concrete sub-base. For example, as per IL&FS Environment (2017), the Delhi Development Authority has used close to 5 lakh MT of recycled aggregates as sub-base for roads. Indian Road Congress has permitted the use of produce of C&D waste processing and has issued IRC: 121-2017 "Guidelines for use of construction and demolition waste in road sector".

4.4. Other applications

Approximately half of the output from a C&D recycling facility is loose soil and mixed brick base, which typically has low demand. It is important that these products are also gainfully utilised to enhance sustainability and plant viability. Some applications for loose soil include gardening and landscaping, brick chippings to be used as drainage substrate for green covering and brick sand for tennis courts and other sports facilities. Being bulk of the output, finding long-term sustainable applications for such products will be one of the factors in ensuring success of the recycling facility.

5. Selection of Technology

Achieving technical and financial viability of C&D treatment and recycling facilities is a significant challenge because of reasons such as lack of data, constrained availability of land in urban areas, significant illegal dumping, lack of understanding of environmental damage and limited willingness to pay. There are three interrelated aspects requiring data and analysis i.e. selection of technology, business model and location. We discuss these in the following paras.

5.1. Technology Options and Selection

There are three main considerations driving the selection of the technology. First, whether recycling is feasible on a construction site in a standalone mode or alternatively is land available to develop a stationary facility. Second, the quantum and the nature of waste being generated. Third, the distance between major waste generating locations and the proposed recycling project site.

Based on these three considerations, a choice between two main types of technologies needs to be made. The two options are. (a) mobile crushers of different types which can be placed in-situ and (b) integrated stationary processing plants capable of washing, crushing, and segregating different types of waste. For all large-scale, green-field and redevelopment projects, in-situ mobile units are relevant. There are several reasons for this solution. First, it maximizes opportunities for recycling and reuse as the developer can integrate it in the demolition plan. Second, it minimizes transportation, thereby reducing cost and equally importantly, carbon emissions. Third, mobile units can be moved from one project to another and hence provide a flexible solution.

For recycling of C&D waste at city or town level, the wet processing integrated plants are appropriate in most cases the nature of the incoming waste stream is heterogenous. In larger cities, particularly where significant infrastructure projects such as metro development, new airports or greenfield townships are being planned, it will be useful to provide an additional crushing option as significant quantity of demolished concrete waste can be expected, particularly till the time mobile units become more prevalent.

An additional option that should be evaluated as part of the technology selection is the machinery for value added products such as manufacturing bricks, paver blocks etc. should be considered because the demand for recycled materials such as sand and aggregates may be inadequate. This evaluation will require understanding of the market for raw materials such as sand, aggregates, and soil. A commitment from the State and ULB to off-take a certain minimum quantity, say 30 percent, of the value-added products for development projects have a potential to significantly bolster the financial viability.

5.2. Quality Control and Testing

Ensuring quality control is critical to build confidence of the construction industry for addressing the mindset barrier. Systematic quality control will also establish a case for increasing the limits under the standards. Quality control calls for investment by establishing an in-house laboratory facility to perform basic tests, such as water absorption, specific gravity, testing for deleterious materials like chlorides and sulphates and sieve-analysis. A testing system with documented procedure for taking representative samples, frequency of testing and periodic certification by external third-party needs to be adopted. Further, capacity development of plant managers, operators and labour is required to enhance their understanding of the technical aspects and to develop customer orientation.

6. SINTEF Pilot projects of C&D waste recycling in India

6.1. Godrej Construction Materials; Mumbai

The Construction Materials business under Godrej Construction operates an RMC plant, a crushing unit for dry recycling of concrete debris and a fully automated concrete block and pavers manufacturing plant in Vikhroli, Mumbai. The recycling plant has a capacity of 300 TPD and the blocks and pavers plant have the capacity to produce 36,000 solid blocks per day and 54,000 Pavers per day. Marketed under the Godrej Tuff brand, these blocks and pavers are produced totally with recycled aggregates from Construction and Demolition waste. The objective of the project is to demostrate the added value of using concrete blocks with recycled aggregates. This means to document the technical performance of the pilot in each stage – from the source of the demolition to the placing of the blocks and evaluate the net green house gas emission for concrete pavement products by including the natural CO2-binding in the Environmental Product Declaration (EPD) by life cycle analysis.

The project, using a third-party testing house, systematically covered sampling, testing and documenting each stage of the whole cycle of demolition, recycling, block making and laying the recycled concrete block back into the prestigious Mumbai Metro construction project in the Aarey-Goregaon (E) station building. This also included testing a concrete block made with the recycled concrete in the SINTEF lab in Norway for evaluating the CO2 binding properties and the resultant positive impact on lowering the carbon footprint. The project report is currently being analysed and compiled for publication.

6.2. L&T – CIDCO Housing project, Ulwe, Navi Mumbai.

L&T has bagged the contract from CIDCO to construct 23,432 dwelling units at various locations in Navi Mumbai. This project, under the Pradhan Mantri Awas Yojana (PMAY) envisages construction of dwellings for the Economically Weaker Section (EWS) and Low-Income Group (LIG). A large part of this project is precast concrete and L&T has set up a PEB factory at Ulwe, Navi Mumbai where the precast concrete would be produced. Recycled concrete aggregates was proposed to be used for the PEB Grade slab (M 20) and for lean concrete (M 10).

Demolished concrete from Mumbai Metro project, Line no:5, Thane city was recycled at Metrro waste handling Private Limited plant at Kalyan Phatta, set up for the Thane Municipal Corporation. It was decided to use RCA fine aggregates A detailed sampling and testing schedule was prepared beforehand and testing of the recycled aggregates were conducted at a third-party laboratory before dispatch. Based on the physical properties of the RCA, the mix design was suitably modified. RCA was used at 100 percent for lean concrete, while 50% of the fine aggregate was replaced with RCA for grade slab concrete (M 20).

A total of 268 MT of RCA was supplied to the site and close to 500 m3 of concrete produced. 150.5 m3 of M 10 lean concrete and 342.55 m3 of Grade slab concrete M 20 was produced with this RCA. The concrete was cohesive and the compressive strength was comparable to the concrete produced with fine aggregate from natural stone.

7. Conclusion

Scientific management of C&D waste is a key challenge for reducing environmental risks such as air pollution, land degradation and ground water contamination. The current state of play suggests that stakeholders at the federal level are more aware and have issued new policies, regulations and introduced programs. At the city level, there has been limited progress and several barriers still exist. India's rapid urbanisation will lead to an exponential increase in the volumes of the C&D waste generated and resource shortage for construction. To quote John F Kennedy, "when written in Chinese, the word 'crisis' is composed of two characters, one represents danger and the other represents opportunity". The parallel is striking. C&D waste poses a real danger to the environment as we have seen earlier, but when treated and converted to recycled materials it also provides an

opportunity to reduce the extraction and use of virgin aggregates, that are depleting rapidly. Effective policy setting, enforcement of regulatory provisions, capacity building and scientific waste management practices are powerful tools available with us to achieve the twin objectives. It must also be mentioned here that there have been some "islands of excellence" in India in the area of recycling C&D waste effectively and utilising in construction, the prime examples being IL&FS facilities in Delhi and Godrej in Mumbai, where recycled concrete aggregates is being successfully used in manufacturing high quality concrete blocks and pavers. The research analysed technical and financial options to develop business models based on principles of polluter pays, risk mitigation and market linked prices. An optimal business model can be selected based on a range of scenarios presented. Continued role of state and ULBs through policy enablers and capacity development were identified as other critical success factors.

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Resilient Energy, a business consultancy firm is an associate of SINTEF in the C&D WIN Project; "Treatment and Recycling of C&D Waste in India". Kshemendra has led European companies in India for over 12 years as the Managing Director of Sapa Extrusions India and Orkla India (Elkem & Borregaard) and has over 32 years of experience in the Materials, RMC and Aluminium industry. He is a strategic leader with proven track record in business turn-around, change management and establishing profitable growth. Kshemendra is a B-Tech in Civil Engineering and holds a Post-graduate Diploma in Advanced Concrete Technology from the Institute of Concrete Technology UK. He has served as Member- Bureau of Indian Standards: Cement and Concrete Sub-Committee and authored and presented numerous papers on concrete in many international seminars and conferences.

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Outside Cement and Steel: C-PC Polymer Composites based Civil and Structural Engineering Applications

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Highlights of Discussion:

- Current trend of Construction and future expectations from limited resources.
- Reasons to look outside cement and steel in construction applications.
- Possibilities from Polymer composites.
- About C-PC technology and its suitability.
- Performance based categories of C-PC.
- Potential areas ofC-PC applications in Construction and Infrastructure development.

Executive summary

The construction industry is always evolving with new techniques and methodologies. With the global industrial communities setting their sustainability goals for a better future,any new trends andtechnological advancements appearing within the construction industry must have a stronger focus on sustainability.

India is the second-largest producer of cement and steel in the world. Production is driven by increasing demand in sectors such as housing, commercial/ industrial construction and urban infrastructure development.

According to Indian steel association analysis report- 2018, nearly 62% of Steel produced is used in construction sector.In 2018 cement production capacity reached 502 Mt per year and it is expected to grow rapidly to reach 550-600 Mt per year by 2025.

Production of cement and steel is mainly based on thermal energy from coal and other fossil fuel. Power and heat generation account for over two-thirds of coal consumption (three-quarters in terms of weight), followed by iron and steel production (almost 20%), cement (around 5%), and other industries like fertilisers, pulp and paper, non-ferrous metals and chemicals production. The cement sector's share of total consumption of coal in its production will rise from 3 per cent to 5 per cent over the next two decades.

The data from many such studies and practical experiences shows that the construction industry, at least in case of India, is very far away from meeting the sustainability credits. In this regard, newer technologies have to evolve so as to motivate the civil engineering fraternity to deviate from traditional Concrete and steel construction system for the benefit of generations to come.

Other than material consumption the general trend of current construction practices also demands for excess production and usage of Concrete and steel. Few points of concern as seen in the construction practices are enlisted below:

- Fast-track mode of construction with greater dependency on Cement composites.
- Delays and wastage of materials thus hindering the productivity of the system.
- Quality Control issues resulting in over consumption of concrete and steel
- Least scope for Recycling options
- Labour oriented and Time Consuming Process

Rising risk of overconsumption of limited raw material resources, very poor sustainability grades of construction materials along with high skilled labour costs and faster construction cycles have resulted in looking towards other construction/ infrastructure alternatives. With due concern to such limitations of concrete-steel construction, Polymer compositetechnology can be concrete and steel's alternative under appropriate occasion.

Chetana-Polymer Composites (C-PC) building system is a novel approach wherein a combination of new composition of polymer composites and elements of building systems are integrated in order to meet the performance & stability requirements of any building.

In particular, C-PC relates to a combination of new recipe of filler based polymer composite and designing building elements such that all requirements of a building are met by the same composition. C-PC system is free from cement and steel but targeted to behave as a member/material equivalent to Cement and steel composites used in construction applications.

C-PC building system is a Fly ash based polymer composite with different combination of micro materials to create a robust particulate system held together by a superior polymer matrix. The production process is simple and less energy intensive with

a greater scope for recyclability of ingredients then and there at the production facility. The schematic production workflow of C-PC building systems is shown in Figure 1.

Based on its Performance under loading C-PC is categorized into three basic grades.

Grade 1 – 20 to 50MPa strength under compression, tension and flexure.

Grade 2 – 100 to 200MPa strength under compression, tension and flexure.

Grade 3 – 250 to 400MPa strength under compression, tension and flexure.

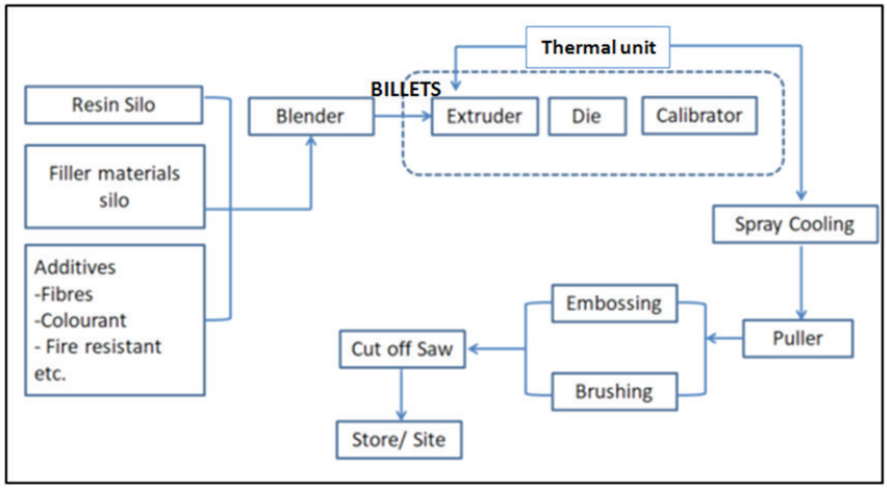

Figure 1.Production work flow of C-PC building systems- Simple Extrusion Process

C-PC building system is advantageous over concrete and steel construction system when used in appropriate situation as per the performance requirements from different grades of C-PC. Few points of C-PC benefits over conventional construction practice are enlisted below and a brief comparison of C-PC with Steel/ GI system is given in Table 1.

- Factory made product- quality control with less manual labour.
- Carpenter friendly for customization.
- A better sustainable solution utilizing large quantity of industrial wastes and byproducts.
- Significantly reduced weight of structural elements.
- Automation friendly and advantageous for machines as in 3D printing.

Table 1. C-PC Building System Benefits over GI/steel system

Features		C-PC system	Steel/GI system
	Durability	100% Rust proof	Prone to corrosion by rusting
	Handling & Maintenance	Light weight with Zero maintenance	Heavy weight with Frequent maintenance and check
	Strength	Sufficient strength with least weight per area	High strength with greater weight per area
	Salvage value	Almost everything can be reclaimed for salvage	Comparatively very less reclamation for salvage
	Recycle Scale	Completely recyclable with minor energy expenditure	Partly recyclable with major energy expenditure

Some of the prime areas for applications of C-PC system are as compiled in Table 2 with few more areas covered under following discussion.

Table 2. C-PC Building System Applications

Sl.no	C-PC Building systems	Description
1	Non-structural system	□ Doors and door frames □ Windows and window frames □ C- Doors and window shutters
2	Internal Partition walls system	□ Sections of thickness 50 mm to 100 mm A- with infill B- without infill
3	External wall system	□ Sections of thickness 100 mm to 200 mm A- with infill B- without infill
4	Structural systems	□ Slab □ Beam □ Decking □ Columns □ Infill Columns
5	Finishing systems	□ Building exterior Protective panels □ Decorative panels □ Floor screed

Other Potential areas of C-PC applications in Construction and Infrastructure development can be briefly categorized as follows.

- Decking Sheets and Roofing sheets.
- Purlins, Angles and Channels.
- Single story portals, Interior use Columns, Light beams, Trusses, Rafters.
- Plain sheets for form works, partitions, suspended ceiling and water proofing.
- Designer Furniture and Staircase railings.
- Pavers, Fencing, Compound walls and Gates.
- Kerb stones and Traffic dividers for all roads.
- Electrical Power transmission and insulation accessories / fixtures.

Test result from the Initial trials on C-PC material is presented below in Figure 2a and 2b. The approach of Fly ash based polymer composites exhibits acceptable results under different mechanical stresses and offers positive challenge to be accepted by the construction community for its further improvisation.

सिपेट : सेन्टर फॉर स्किलिंग एण्ड टेक्निकल सपोर्ट (सी एस टी एस)
रसायन एवं पेट्रोरसायन विभाग,
रसायन एवं उर्वरक मंत्रालय, भारत सरकार
नंबर 437/A, हेब्बाल इन्डस्ट्रियल एरिया, मैसूरु - 16.

CIPET सि पे ट
probe - perform - practice - Plastics

CIPET : CENTRE FOR SKILLING AND TECHNICAL SUPPORT (CSTS)
Department of Chemicals & Petrochemicals,
Ministry of Chemicals & Fertilizers, Govt. of India
437/A, Hebbal Industrial Area, Mysuru - 570 016.

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Sl. No. : 26844

TEST REPORT

Issued to: Chetanna Exponential technologies

Chetana House,No 3/1 10 th
Cross,Vasanthnagar Bangalore KA IN 560 052

Bangalore

ULR No: TC872120000000478F
Test Report No: 17654-A
Date : 29-01-2021
E-Mail
Your Ref. No. :
Dated : 25-01-21

Test Report as Per Standard :

Part-A PARTICULARS OF SAMPLE SUBMITTED

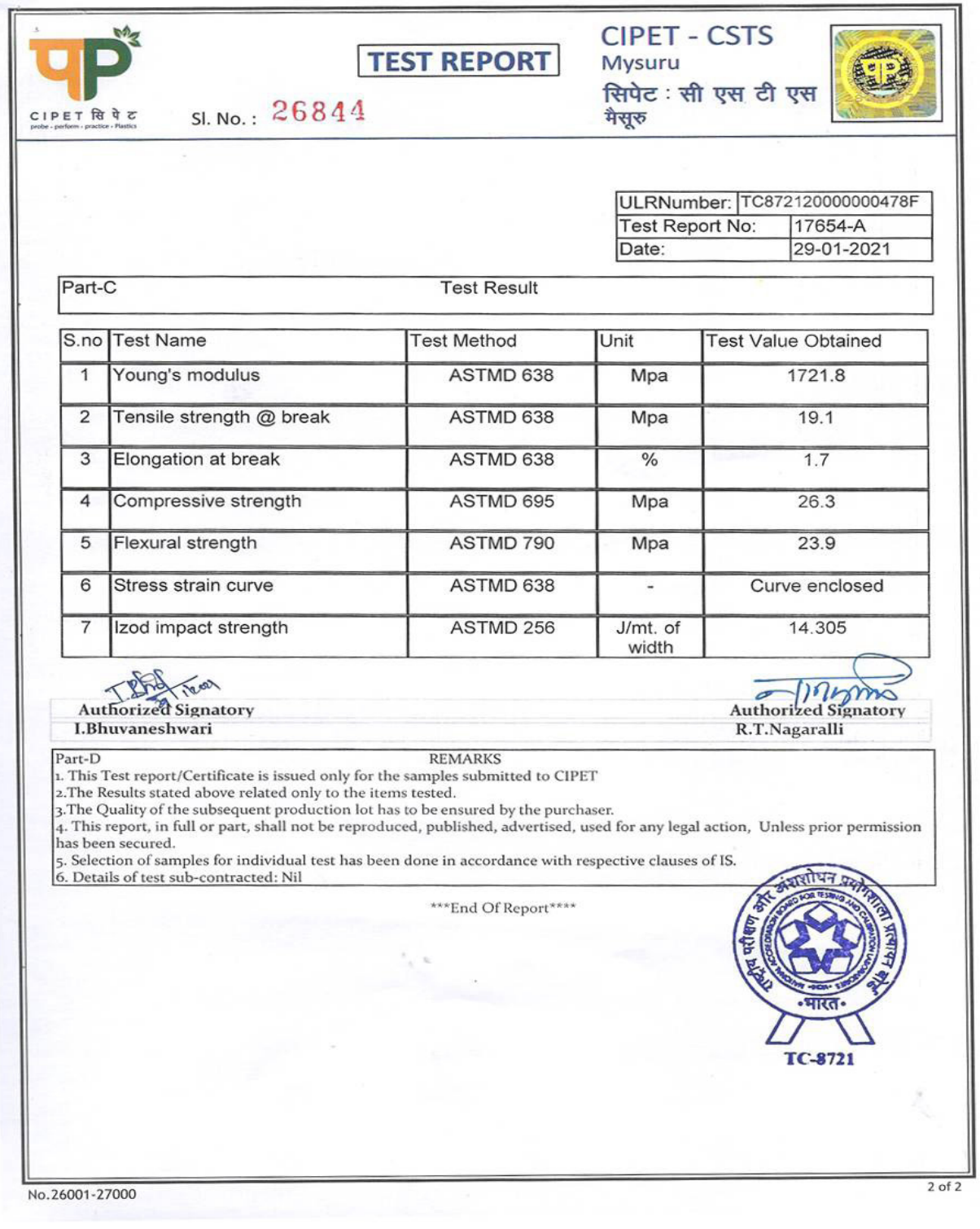
a) Name of the Sample	:	Plastic components
b) Grade/variety/type/size/class	:	Nil
c) Declared value, if any	:	Nil
d) Code No.	:	CPC-03
e) Batch No. and date of Manufacturing	:	Nil
f) Quantity	:	7 no.Sheets samples
g) Mode of Packing	:	No packing
h) Sealed or not	:	Not Sealed
i) Any other information	:	Date of sample received : 25-01-21 Date of Initiation : 25-01-21 Date of completion : 29-01-21

Part-B SUPPLEMENTARY INFORMATIONS

a) Reference to sampling procedure	:	Supplied by the party
b) Supporting documents for the measurement taken and result derived	:	As given in Part-C
c) Deviation from the test method as prescribed in relevant work instructions, if any	:	Nil

21010632

TC-8721



CIPET - CSTS
Mysuru
सिपेट : सी एस टी एस
मैसूरु

TEST REPORT

Sl. No. : 26844

ULRNumber:	TC872120000000478F
Test Report No:	17654-A
Date:	29-01-2021

Part-C — Test Result

S.no	Test Name	Test Method	Unit	Test Value Obtained
1	Young's modulus	ASTMD 638	Mpa	1721.8
2	Tensile strength @ break	ASTMD 638	Mpa	19.1
3	Elongation at break	ASTMD 638	%	1.7
4	Compressive strength	ASTMD 695	Mpa	26.3
5	Flexural strength	ASTMD 790	Mpa	23.9
6	Stress strain curve	ASTMD 638	-	Curve enclosed
7	Izod impact strength	ASTMD 256	J/mt. of width	14.305

Authorized Signatory
I.Bhuvaneshwari

Authorized Signatory
R.T.Nagaralli

Part-D — REMARKS

1. This Test report/Certificate is issued only for the samples submitted to CIPET
2. The Results stated above related only to the items tested.
3. The Quality of the subsequent production lot has to be ensured by the purchaser.
4. This report, in full or part, shall not be reproduced, published, advertised, used for any legal action, Unless prior permission has been secured.
5. Selection of samples for individual test has been done in accordance with respective clauses of IS.
6. Details of test sub-contracted: Nil

End Of Report*

TC-8721

No.26001-27000

2 of 2

Figure 2a: Test for C-PC 03 at CIPET, Mysuru.

With the availability of better sustainable options from Polymer technology, it becomes the responsibility of Civil Engineers and Material Scientists to develop alternatives to concrete and steel and identify its suitability for implementation on a vast scale. Such changes in construction and infrastructure materials and practice will not only save on over usage of cement and steel but also justifies the act of present day practice towards a more sustainable construction industry of future.

Innovative materials developed for construction industry

Dr. R. Nagendra, Chairman – Organising Committee, Concrete Panorama & Deminar-2021

Indian Concrete Institute - Bengaluru Centre, Karnataka is organizing the "CONCRETE PANORAMA AND DEMINAR - 2021: Two-day International Seminar cum Deminar - Live Product Demonstration & Exhibition" is Entitled on: ALTERNATIVE MATERIALS AND INNOVATIVE TECHNOLOGIES IN CONCRETE CONSTRUCTION" showcasing the latest developments in India and aboard during 16-17 March 2021 at B.M.S. College of Engineering, Basavanagudi, Bangalore.

The beginning of civilization as we know it really started with a series of material innovations; the Bronze Age and the Iron Age set us on the path to where we are now, after all. Skyscrapers would have never reached such heights without developments in steel and high performance concrete, for example, and facades would have never slimmed down without thin-shell concrete.

In a time that is so buzzing with technological development, we cannot help but salivate a little at the material prospects for civil engineering industry that are just on the horizon. It is time to see what drastic innovations may be leaking into the world of construction in the near future. Two innovative rebar alternatives are - Fiber Reinforced Polymer (F.R.P.) and Aluminum which are non-corrosive as well as light in weight in comparison to traditional steel.

FRP Reinforcing bars

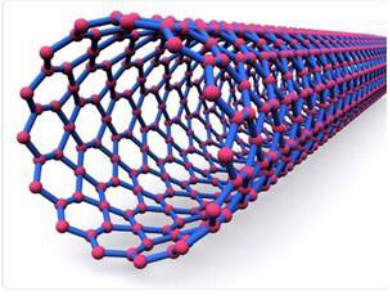
Aluminium Reinforced bench

The great downfall of concrete—the world's most widely used building material—is unavoidable cracking, caused by exposure to water and chemicals.

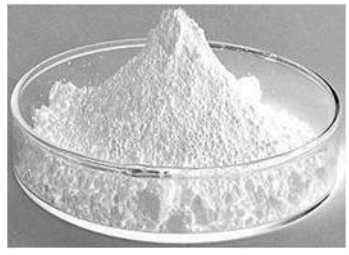
But a new development from a team in the Netherlands could extend the life of concrete , by infusing it with bacterial spores that patch up cracks when water seeps through. Plans are in place to make this self-healing concrete commercial in the coming years

Nanotechnology is one of the most active research areas that encompass a number of disciplines, including **civil engineering** and **construction** materials. It is the art and science of manipulating matter at the nanoscale. It is an enabling technology that allows us to develop materials with improved or totally new properties. Nanotechnology is the use of very small particles of material. A nanometer is a billionth of a meter.

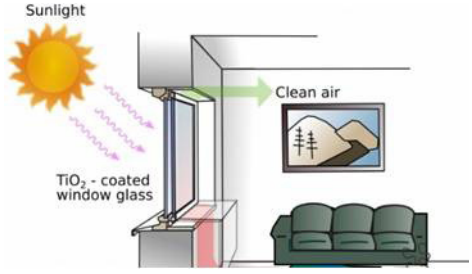
Use of nano fillers in concrete improves its weakness in tension and result in concrete with greatly improved stress-strain behaviour The addition of nano silica fume improve durability of concrete structures.



Carbon Nano tube



Nano Silica



TiO2 applied window

TiO2 is a white pigment and can be used as an excellent reflective coating. It is hydrophilic and therefore gives self cleaning properties to surfaces to which it is applied. The addition of small amounts (1% wt) of CNT's can improve the mechanical properties of samples consisting of the main portland cement phase and water.

AEROGEL

Aero gel is a solid with the lowest known density. It stands up to 2000 time's greater load than its own weight. It has extremely low thermal conductivity; the material is very suitable to limit the heat losses of buildings. Its melting temperature is 1200 °C.

In Concrete Planet: The Strange and Fascinating Story of the World's Most Common Man-Made Material (Prometheus Books, 2011), author Robert Courland writes: "If the Romans had used steel-reinforced concrete—which they did not have—to build their beautiful bridge in Alcántara, Spain, the bridge would have to have been rebuilt at least 16 times by now."

The production of **construction materials** requires energy and generates greenhouse gases. In order to increase the service life of structures **innovative materials** offer opportunities to change the way in which we construct and retrofit buildings. They give added value in terms of increased performance and functionality.

Waterproofing of structures – Why is it important ?

M N Ramesh, Manging Director, Talrak Construction Chemicals Pvt. Ltd., Bangalore

Waterproofing is a key activity of the building process. However, sometimes waterproofing problems require individual solutions. That is why a skilled technical team should work together with designers to analyse each situation in order to develop a customised solution which meets the individual requirements of a given project. In other words the waterproofing should commence from the drawing board stage !

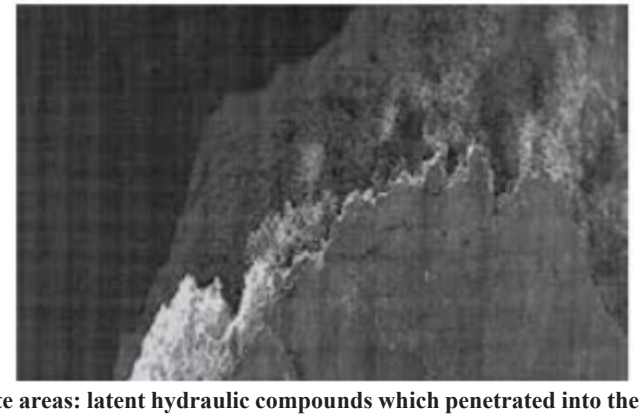
Why is waterproofing so important? Each year around the word, massive amounts of money are invested into infrastructure, public, and private building projects. According to a report on distress in building structures, 80% of damages ultimately relate to waterproofing issues. Investing in high quality waterproofing not only protects construction elements against water ingress but also ensures resource efficiency, low maintenance costs, and high return on investment in the long run.

New construction projects

In new construction, external basement waterproofing and waterproofing under the foundation plate protect against water ingress from surrounding soil. TPO roofing membranes protect flat roofs that can last for 50 years in any climatic region around the world. Liquid applied polymer coatings protect balconies and terraces against weathering. Cementitious materials with drinking water certification safeguard our drinking water on the inside of potable water storages. In commercial building projects decorative flooring combines design with easy cleaning. In industrial facilities highly resistant floor coatings protect concrete floors from traffic or contamination by oils, acids as well as provide slip resistance. Joint sealants and injection gels help to successfully build underground infrastructures such as new metro lines and tunnels. Water repellents protect buildings and infrastructure from water ingress while special coatings protect façades in coastal areas against the aggressive and salty air.

Remedial Waterproofing systems

In restoration projects cementitious crystallizing waterproofing materials provide waterproofing from the negative side such as in basements or tunnels. Special fast setting blitz mortars can even stop flowing water. Curtain injection or area injection are special solutions that are able to waterproof the external side of a construction without direct access. Horizontal barriers stop rising damp (capillary action) in walls while restoration plasters support the drying process by preventing salts from damaging the building substance. Moisture control systems protect against vapor migration through the concrete slab and prevent flooring failure. Infrastructure forms the heart of trade and commerce in a modern world. Its reinforced concrete structures need to be maintained for secure transportation today and tomorrow. Crack injection technology is capable of repairing cracked concrete structures, whether against active water pressure or just for restoring structural strength.



Electron microscope scan: White areas: latent hydraulic compounds which penetrated into the pore structure of the substrate – and reacted to form a pore blocking crystal.

Key parameters of a Negative side Waterproofing System

For a successful waterproofing of a structure from the negative side, the ideal product should have the following properties:

- The waterproofing product should be mineral based just like the brick or concrete substrate and it has to become one with the substrate.
- The waterproofing product ideally penetrates a little into the substrate. That way it cannot be pushed off by the water pressure.
- The material has to be open to vapor diffusion so that water vapor can penetrate the cured coating.

- The material should be free of clorides so that it does not harm the steel reinforcement.
- The material should resist high water pressure from the negative side.
- The product should be easy to apply.
- The product should have self-healing properties to avoid leakages from minor cracks.

The mineral substrate has to be sound and solid as well as free of grease, oil and loose particles. Prior to application, the substrate has to be wetted, standing water has to be avoided. Dusty or salt-contaminated substrates are primed with a crystalline stabilizing penetrating primer.

Salt laden Substrates

When sufficient crystallization has taken place, the pressure in the capillaries will get so high that the building material is destroyed. The material loses its mechanical strength, and it becomes brittle, resulting in a damaged surface.

Salt Efflorescence

A typical sign of salt contamination is salt efflorescence, mostly seen as a whitish substance on the surface of masonry or concrete. Often the salts are transported from the surrounding soil through the capillary system of the building materials by rising damp. After a while, paints or conventional plasters are simply pushed off by the pressure of salt crystallization.

For restoring salt contaminated substrates, products that can be used should with tlow viscous product based on a combination of polymers and silicates. When it is sprayed onto the surface of the substrate it penetrates into the capillaries. It reduces the pore volume, lowering the danger of renewed salt efflorescence. It also increases the chemical and mechanical resistance of mineral building materials. The polymers ingredient encapsules the salt molecules and reduces their mobility preventing the leaching out of efflorescence.

Concluding remarks

In summary, the longevity of the structures is depending on how much resistance the building element will offer to the water ingress into the structure. The water leakage not only reduces the durability but also hampers the serviceability or usability of the structures. Hence a good waterproofing system installed in the structure would address the issues of long term and usability aspects.

Recent developments & Innovations in Processing Technologies for development of Eco-friendly Slag Aggregates from the steel Industry

Dr. L R Manjunatha, Associate Vice President –JSW Cement Limited and
Honorary Chairman , Indian Concrete Institute ,Bangalore Centre
D Satish Kumar, Research and Development, JSW Steel Ltd, Bellary

He is one of the leading Techno Commercial expert in India with over 27 years of rich and valuable work experience having worked with leading corporates and MNCs and 11 years of research experience in the field of Ready-mixed Concrete , Sustainable Green building materials, solutions, Fiber reinforced Concretes and floorings, Mineral and Chemical admixtures and Green technologies to create a sustainable and durable constructions solutions for the future and for our next generations .He has published more than 30 research papers and has presented papers at more than 50 conferences in India and Abroad, and Given more than 550 student presentations at Engineering and Management colleges across length and breadth of the country both in physical and webinar presentations on topics of interest related to concrete, HPC, Green building materials, RMC Topics ,Special cements ,Minerals additives ,Construction quality Managements ,Alternatives to River sands, Geo polymer concretes, Sales training, Lean construction management ,Construction quality management etc

Abstract

The iron and steel making processes generate huge amount of slags as by-products which when cooled resembles aggregates. With increasing capacity of steel production, significant efforts and investments have been made into research over the years to develop the slag processing technologies which enable re-use of slag either directly or through development of slag-based products. Owing to the fact that the physical properties of iron and steel process slags match the properties of natural aggregates, it is found that one of the major application areas where large quantities of slag can be utilized is in road and civil constructions as replacement of natural aggregates. Many steel plants, including JSW steel has extensively worked on various granulation techniques and processing methodologies to convert Iron and steel slags into coarse and fine aggregates and inputs for other applications. JSW has developed both coarse and fine aggregates from both iron and steel slags through some innovative technologies. It has developed concrete design mixes for roads and construction using processed slags which can cater to the demand for eco-friendly alternative aggregates to the construction industry. The present paper will highlight the strategies and processing techniques developed for converting slags into products, its characteristics and its usage in various industries.

Introduction

With ever increasing demand of raw materials for roads and construction leading to rampant reclamation of natural resources, the eco-balance of the environment is under constant strain. Hence, there is an urgent need to preserve the precious natural resources and find newer materials for this purpose. Some of the feasible and economical solutions that have emerged through long research activities are to reuse the industrial process wastes through recycling or reprocessing. Promoting the use of iron and steelmaking slags as replacement of aggregates in roads and civil construction represents an excellent success story consistent with these goals. Slags are the main wastes generated during iron and steel production in the steel industry. Steel plants generate around 400-500 kg of total slag per tonne of steel produced. Slags are generated at two different stages of steel production, Iron making and Steel making known as BF slag and Steel Slag respectively. These slags are in liquid state and are solidified in air after dumping in a pit or granulated by impinging water stream. Air cooled slags are larger in size (> 10 mm) hence requires crushing and sizing and is similar to coarse aggregates. Water granulated slags has size close to river sand and or fine aggregate. Because of the high temperatures (about 1500 °C) during their generation, slags do not contain any organic substances, shells, clay etc which is a key advantage. Slag aggregate can be used as a construction material in unbound applications (where the aggregate is not bound) as well as in bound applications (mixtures which contain binding agents like cements, bitumen or a substance that has binding properties in contact with water). Until recently, slags were not regularly utilized in civil construction due to the ease in availability of natural materials, lack of awareness of its benefits, non-availability of guidelines, limited slag processing techniques. With numerous studies published in recent past, on durability and long term impact of slag usage in roads and construction and introduction in IS-383, it is now well established that processed slag can be used as a safe replacement for natural aggregates for roads and civil construction. Factually, use of slag aggregates in construction dates back to the Romans who used crushed slag from the crude iron production of that time to build their roads. Slag is particularly useful as an aggregate due to it's high mechanical strength which exceeds many natural aggregates. In general, the properties of iron and steel slag aggregates are comparable with the properties of natural aggregate. In some

specific cases, slag aggregates are even superior to natural aggregates. Contrary to the earlier concept, iron and steel slag is not a waste any more and is a useful product capable of helping ecological balance and economic benefits.

Air Cooled Iron Slag – Coarse and Fine aggregate

Air-cooled blast furnace slag can be defined as "the material resulting from solidification of molten blast furnace slag under atmospheric conditions. The slag thus produced is in the form of large boulders. The air-cooled BF slag can be crushed, screened and directly used as coarse aggregate for roads and bases, asphalt paving, railway ballast, landfills and concrete aggregate. The solidified slag has a vesicular structure with closed pores. Air cooled BF slag exhibits similar mechanical properties as that of a natural aggregate such as good abrasion resistance, good soundness characteristics, high bearing strength etc. This slag can also be crushed to small sizes using a vertical shaft impactor and screened to convert it into fine aggregate. Fig 1 shows the Air Cooled Coarse and Fine aggregates. This light weight sand is ideal for plastering applications and matches to IS-2116(sand for masonry mortars) and IS-1542 (sand for plaster).

Fig 1: Air Cooled Coarse and Fine aggregates from iron slags

Granulated Iron Slag – Fine aggregate

Iron making slag granulation technology has been in regular use for converting it into glassy granules for use in portland slag cement making along with clinker. Recently ground granulated slag (GGBFS) is also developed using the granulated slag for used as replacement of ordinary portland cement by ready mix concrete (RMC) manufacturers. However increased steel production and lesser uptakes by cement industry force steel makers to look for alternative applications. Granulated blast furnace slag (GBS) is physically similar to sand but has low density and has strength issues when used in concrete directly and hence is not used as replacement of river sand. Here, it is important to mention that the property requirement in granulated slags for use in cement and as aggregate is different. Slags to be used for cement making requires high glassy phase (>90%) whereas slags to be used as fine aggregate must have sufficient density (> 1400 kg/m3) or specific gravity (> 2.5). This is a standard property to meet the weight requirement in cubic meter of concrete. At JSW steel, a new processing technique [6] 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. Step 1 involves the optimization of granulation parameters to achieve porosity free granules and second step changes the shape and size distribution using a vertical shaft impactor and set of screens. Fig 2 shows the slag sand developed from granulated slag.

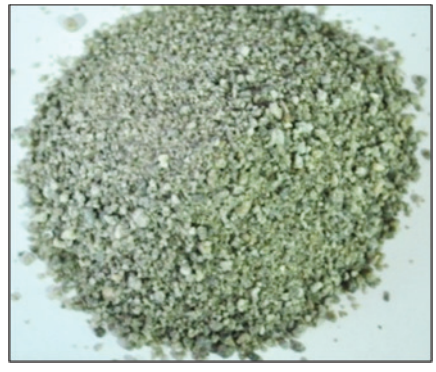


Fig 2: Ironmaking slag sand

The processed granulated blast furnace slag (PGBS) was similar to 100% true river sand. 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. JSW steel has become the first steel plant in the country to market and sell processed granulated slag or Slag Sand as replacement of river sand.

Air Cooled Steel Slag – Coarse and Fine aggregate

Air cooled steel making slag from BOF (Basic oxygen furnace) or EAF (electric arc furnace) the two widely used processes of steel making, constitutes 75-80% of the total slag generated in the steel making process. These steel slags are a dense rock like material and can outperform natural aggregates in terms of resistance to crushing, skid resistance, durability and adhesion. However, variations in compositions, size and recovery components, demand different treatments for BOF and EAF steel making slags. BOF slags due to volumetric instability in the presence of water whereas higher density and irregular shape of

EAF restricts its applications. These concerns have also been addressed by the steel makers with the development of steam ageing for BOF slags and use of impactors for EAF slag. All steel slags are inevitably subjected to crushers, magnetic separator and screens to recover metallics. This metallic separation process breaks slag into different sizes. Slag sizes 10-20 mm, 20-40 mm and 40-80 mm can be used as coarse aggregates. Several experiments were conducted at JSW steel for evaluating the properties of concrete made by coarse steel slag (both aged BOF and EAF) as coarse aggregate. These experiments include water absorption, alkali-silica reaction, resistance to degradation and soundness of aggregates as well as mechanical properties of concrete specimens such as compressive strength, flexural strength, tensile strength and modulus of elasticity. Not only concrete but slags can also be used for road construction in granular sub base, dry lean concrete and asphalt mix. Steel slags are recommended to be used in wear resistant asphalt layers as chippings. Studies have also indicated that diluting steel slag with inert materials, such as gravel and sand, can reduce the swelling potential and can be used as structural fill material in landfill embankments. pavement surfaces incorporating steel slag have shown superior skid characteristics than asphalt surfaces incorporating natural aggregates.

New processing methodology has been developed at JSW Steel to convert the crushed steel slag into fine aggregate for replacing river sand as shown in Figure 6. In the developed process, the crushed slag is subjected to vertical shaft impactor to control the size and change its shape from angular to rounded. The size and shape of the processed slag particles are controlled by the feed rate and rotor speed. The product is further subjected to air classifier for separation of ultra-fine fractions (< 75 microns). The developed steel slag sand matches the specifications for fine aggregates. Cube tests conducted using the developed steel slag as fine aggregate show improved strength than the river sand owing to its higher density. Fig 3 shows the air cooled coarse and fine aggregates from iron slags

Fig 3: Air Cooled Coarse and Fine aggregates from steel slags

Granulated Steel Slag – Fine aggregate

Recently new technologies of water granulation (close system) and atomization (open system) have been developed and are in practice in full scale by steel makers to granulate steel slag. These technologies help in separation of the metal and slag and also wash out free lime and MgO. Sudden quenching, of the molten slag, leads to differential contraction of metal and slag and results in good separation of both. The resulting granulated slag has good stability, size, and shape control with high glassy content. Granulated steel slags have been successfully utilized as 100 % replacement to fine natural aggregates in roads. Both steel making furnace and blast furnace slags have been successfully used in spray sealing and asphalt applications. It is now well established that steel slag can be processed into a coarse or fine aggregate material for use in dense and open-graded hot mix asphalt concrete pavements and in cold mix or surface treatment applications. Fig 4 shows the slag sand developed from granulated steel slag.

Fig 4: Steelmaking slag sand

In general Steel slags are heavier than iron slags due to the presence of higher Fe content, and hence the combination of BF slags and Steel sags have been found to be suitable for many applications where restriction in weight of the concrete is not a concern. In the recent past, the major attention of the steel plants is drawn to processing and quality management of iron and steel slag products matching to the broad range of civil applications. Subsequent to sustained testing and studies, the slag products have cleared environmental

standards in many countries and are being used prominently in various applications with slag products occupying a major market share. Key Characteristics and applications of Iron and steel slags in cement and construction are shown in Table 3. In the Indian context too, the acceptance of slag product as a replacement in roads and civil construction is on the increase.

Table 5: Characteristics and applications of slags

Slag	Condition	Characteristics	Applications
Iron Making / BF Slag	Air/Water Cooled Slag	Size, high strength and No alkali-aggregate reaction	Coarse aggregate for concrete
		Size, high strength and Hydraulic property	Coarse aggregate for Roads
		Thermal insulation	Raw material for rock wool
		Fertilizer component (CaO, SiO2)	Fertilizer
	Granulated slag	Cementitious phases and Strong latent hydraulic property	Clinker making
			Blending material for Slag cement and concrete
		Latent hydraulic property, large angle of internal friction and large water permeability	Material for civil engineering works and ground improvement material
		Size and free from impurities	Fine aggregate for concrete
		Light weight	Fine aggregate for Mortar and Plaster
		Fertilizer component (CaO, SiO2)	Fertilizer and Soil Improvement
Steelmaking slag	Air Cooled and Magnetically Separated	Hard, wear-resistant and Hydraulic property	Aggregate for Asphalt and concrete roads
		Large angle of internal friction and high strength	Aggregates for civil foundations and engineering works, ground improvement material
	Granulated and Magnetically Separated	Good Hydraulic property and contains (CaO, SiO2, MgO, FeO)	Raw material for Clinker
			Blending material for Slag cement
			Performance improver and Coloring agent in cement
		Size, strength and free from impurities	Material for civil engineering works and ground improvement material
		Size, strength and free from impurities	Fine aggregate for Roads and concrete and as grit

Conclusions

Iron and Steel Slags are economically viable and environmentally acceptable alternative material for replacing natural aggregates in roads and civil constructions. Effective utilization of these materials has tremendous economic impact, conservation of natural resources and gainful recycling of process by-products. Collaborative efforts and investment into research to develop and validate usage of slag based products in different innovative application areas must be done. Through combined efforts of all stakeholders working together to maximize the utilization of this continuously increasing resource, slag products adding value to the sustainability of the industry and environment can be made into a real success story.

Artificial Intelligence (AI) for making Smart Technology.

-Jyothi Gupta, Architect, Geospatial Data Scientist

Abstract: For decades, technological innovation has been revolutionizing businesses, offering them innumerable long-term benefits and growth. Comparing the buildings of the present to what they were even a few years ago will show massive changes. According to studies, the global smart building market is expected to reach 36 billion US dollars by 2020. AI and smart buildings are an ideal combination to streamline, optimize, and innovate the functioning of buildings. With AI and smart buildings combined together, building managers can ensure improved structural reliability and minimized harmful ecological impacts.

The idea behind this concept is to provide a hassle-free experience to occupants while efficiently utilizing energy resources. Earlier, buildings deployed CCTV surveillance cameras, smoke detection sensors, and other light sensors for safety and efficiency. Today, several other smart sensors like temperature, humidity, CO2, and others are embedded in a building. Cameras and actuators are installed everywhere in a building. Data generated by these sources connect different building components and allow them to interact with each other. With such comprehensive data and intelligence, building managers have complete transparency and control of the buildings' different systems. Now, combined with IoT, AI also contributes to making smart buildings even smarter and more intelligent than ever. From year to year, the construction process changes, as clients require not only the place to live but also want to live and work in a beautiful and efficient buildings. Already a proven fact, that artificial intelligence significantly boosts alternative electricity–it finds the most optimal to place solar panels and wind turbines.

This way, AI in industrial planning is gaining incredible popularity. AI-powered tools analyse the existing industrial plans to make construction even better. A vast number of documents contain data on how people create new buildings, and data scientists analyse construction plans to train machine learning models.

Keywords: Artificial Intelligence (AI), IOT (Internet of Things), Building, Data Science

How is awareness for drink driving campaigns encouraging car sharing?

Introduction

An interview by BBC (bbc.co.uk,2012) affecting young crowd who were killed after crashing their vehicles into a tree, their families were promoting and creating awareness for drink-driving. A recent report by Department of transport (Roadsafetywales,2018) said that driving under the influence of drugs has increased by 65% causing serious injury or death. This study aims to investigate the changes between 2008 and 2010; with their population growth and fatal ratio making the right decision for road safety with statistics suggestion.

Literature review

As per the Road Safety Act (1964) in UK first time there was criminal charge for drink-driving which resulted in reduction of road fatalities from 22% to 15% from years 2000 to 2017. A recent report by Telegraph (Telegraph, Nov 2014) shown various examples for drink-drive campaign believing the figure for casualties has fallen drastically and encouraging other means of transport while driving ensuring safety both the driver and pedestrian. Going through the Regression analysis, which shows the relation between promoting Car sharing with Drink drive campaign by this study.

Research Question

This study will address the question on the How is awareness for drunk driving encouraging ride sharing. To proceed, the research question will be further analysed into two split:

1. Difference between 2008 and 2010.

a. Counts of Killed and Seriously injured (KSI)

b. Population of area

2. As the Total budget is allocated for 2009 in five authority type in England, relationship between

a. Drink Drive campaigns

b. Promoting Car sharing

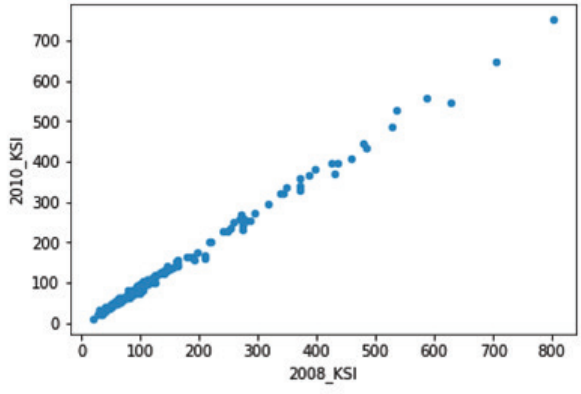


Figure 1 - Scatter distribution of data for count of Killer and Seriously injured on road in 2008 till 2010

Presentation of Data

The data provided for analysis come from England for three years. The variables that apply to the analysis are Count of Death, Populations, Budget allocated for six major safety schemes and Authority types.

This leaves us with information of road safety initiative with 5.14 – 5.21 million individuals in 2008-2010, resided in England.

Methodology

The relationship between deaths and population growth is summarised to visualise the data and finding any outliers. An additional variable is created as a preliminary step to get a summary of individuals available based on their local authority type. When the data is visualised from scatter, histogram or density, frequency plot we then interpret the chosen dataset for performing regression with selecting a single dependent variable. The Total budget described in figure 2 is divided into six categories for safety. Based on the data and above literature study will consider 23% of Drink Drive campaigns needs to promote car sharing which is 8% of the total budget.

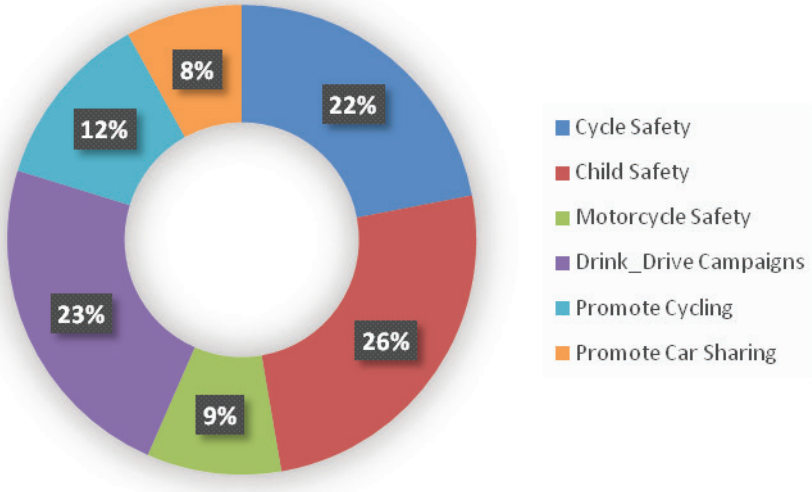


Figure 2 - Total budget shared in six categories to the road safety initiative

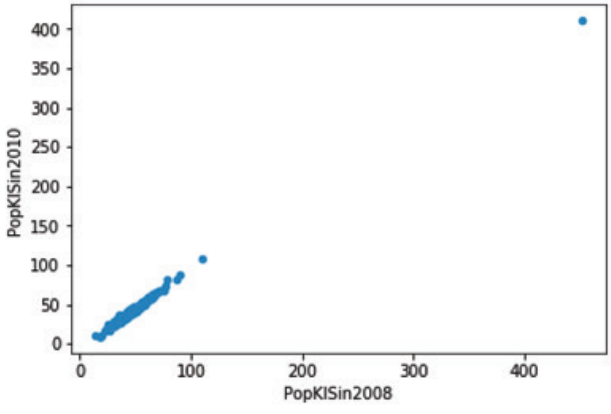


Figure 3-Scatter plot of KSI and population for 2018-10 along with Outlier

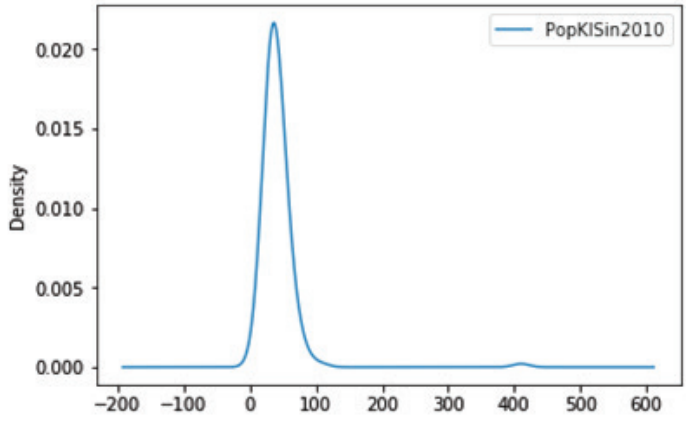


Figure 4: Density plot distribution for 2008-2010 showing KSI against population growth

Discussion

While reading the plot, outlier is seen as 'city of London' area in England where the count of death and population is upto 450-410 number. With the help of 'Import seaborn as sns' visualizing and plotting multiple pairwise distribution in the dataset which creates a relationship with each pair in column, the Independent variable being Drive Drink Campaign showing the univariate distribution of each variable on the diagonal axes. Considering the size of data with 151 rows and 14 columns the scale of the graph is reduced but the purpose is to understand the variation of pattern and gradation of data points on the graph with various correlation between the variables as shown in figure 6 below.

Additionally, the performance shows that managing the road safety system and making awareness of risk, has seen a decrease

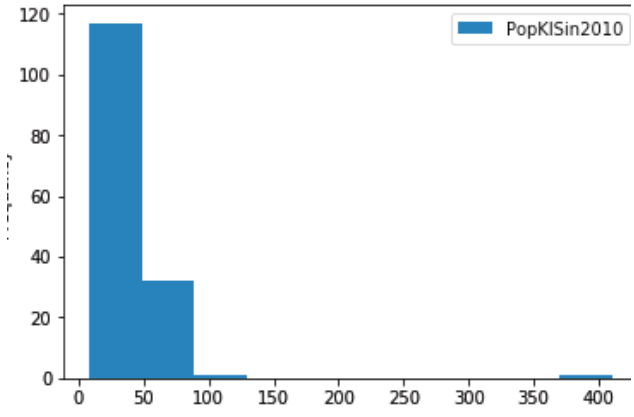


Figure 5: Frequency plot showing difference of counts KIS and population 2008-10

in death compared to 2008-2010 and making a uniform growth, showing the crashes have reduced as law had been abided by all citizen in England.

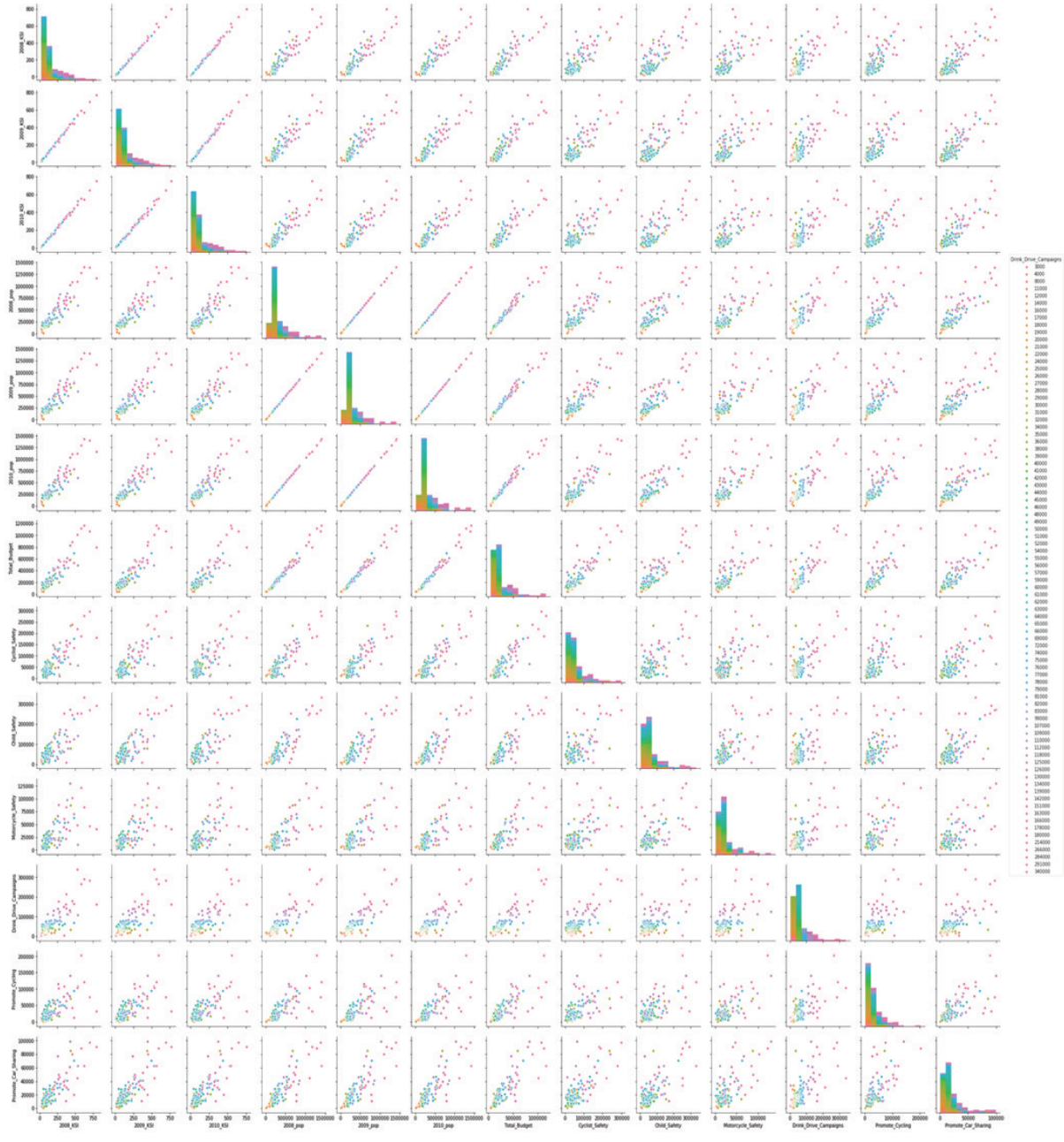


Figure 6 - Each Variable is scatter in X-Y axis to show the multiple pairwise distribution

The analysis of regression is having the relationship between dependant variable (Drive Drink campaigns) and one independent variable (Promote Car sharing), The estimate of the parameter values are from the regression equation (y=mx+c) where m is slope =0.246 and c is the intercept = 6416.63. Based on the values achieved , the estimated regression equation is linear – satisfactory in-order to predict the value of Car sharing gives values form drink- drive campaign.

While investigating the Road safety, the values of the drink drive campaign and promoting car sharing are given X- Y axis of figure 7, the red line passing through the scatter data points is the regression equation. However, while calculating the R square value(Coefficient of determination) which determines the statistical measure (minitabblog,2013) and the p-value the significance level of the model, the output achieved is 0.47 for R squared value and p value as 0.0003 which explains model doesn't have much of variation of the data but it is significant. As the model have less variation in data, based on the residual vs fitted data plot it have fitted the set of observations randomly, so model is appropriate for this research problem.

y = 0.246 x + 6416.635
Rsq = 0.46781474949515955
p-value = 3.698700145868742e-22

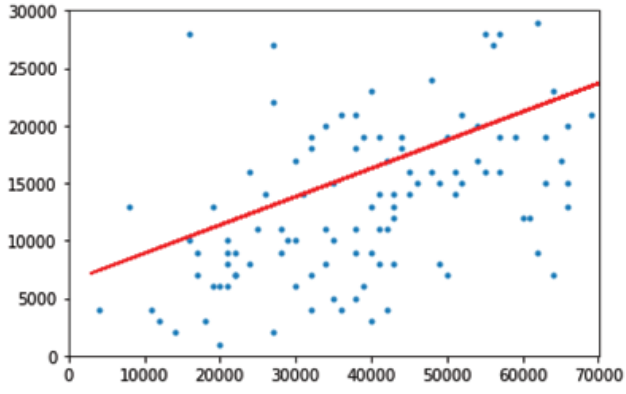


Figure 7 - Least Sqaure Method(LSM) Regression Model

The findings obtained by doing the regression concerning the independent variables in the standard model with goodness of fit being appropriate, the Pearson correlation coefficient (r) is calculated with the independent variable it indicates how the data points are to this line of best fit.(statistic.laerd,2016)

The Positive correlation value has been generated as 0.68 of the model as it basically designed to compare the variables and not influence the units of variables. As shown in figure 8, the data points are clustered near the start of line and later scattered.

Pearson correlation : 0.6839698454575027

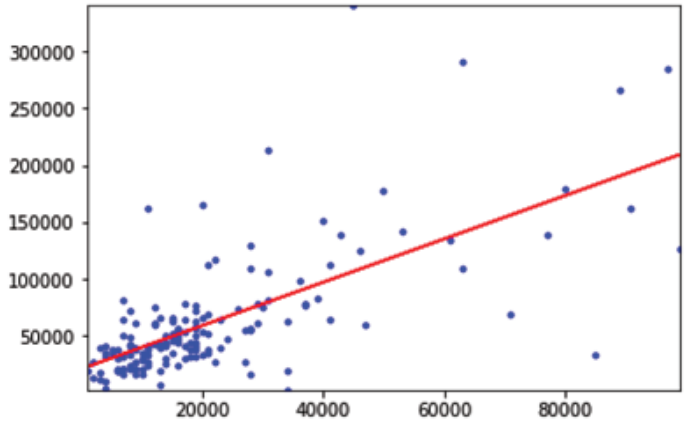


Figure 8: Pearson Correlation coefficient plot

Conclusions

These study analyses the independent variables in the Regression model along with goodness of test /measure of statistics values which confirms the model to be good with its significance values (0.003) and coefficient (0.69). The model's degree of variation in the drink drive campaign variable was 0.46 which should that model predicts the dependent variables.

Based on the statistic of Road safety it is concluded to abide with the Safety law will help reduce the death counts and necessary precaution can be done while drinking by using the shared car services for safety reason on road.

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Properties of Geopolymer Mortar and Concrete using all marginal materials

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Abstract : There is an urgent need to minimize the waste and use them in construction industry. The research reported in this paper is on the properties of concrete by replacing the traditional ingredients with the marginal materials. An attempt is made to replace binder, aggregates and water so that there would be as cent percent replacement of all the ingredients. Conventional cement has been replaced by fly ash and ground granulated blast furnace slag, natural sand by manufactured sand and natural aggregates by recycled aggregates. Alkaline solution was used to activate the binders prepared with recycled water and chemicals of molarity 12. The ratio of sodium silicate to sodium hydroxide was maintained at 2.5. The alkali activated cement concrete/ mortar cubes, cylinders and beams were cast and cured in open air without water or any thermal input. The concrete specimens were tested for compression, split tensile and flexural strength. It was found that the alkali activated cement concrete/mortar attains considerable strength at the age of 28 days and can be compared with control concrete with traditional ingredients. Hence alkali activated cement concrete can be recommended as structural concrete. Also, alkali activated cement mortar can be sued for masonry and plastering.

Key words: manufactured sand, recycled aggregates, fly-ash, ground granulated blast furnace slag, concrete, mortar.

1.0 Introduction

Concrete is the world's most versatile, durable and reliable construction material which is widely used. It is a composite material constituting of cement, fine and coarse aggregates, water and admixture. The drawback of using cement in construction industry is the emission of CO2 into the atmosphere and consumption of raw materials (Satish Chandra, 2002) [1]. To overcome this, geopolymer technology can be used which serves as an alternative binder to ordinary Portland cement.

The base materials for making Geopolymers are aluminosilicates which are rich in silica and alumina. These may be locally available or by-products of an industry such as fly ash, rice husk ash, metakaolin, red mud etc [Wu et al 2019, Canakciet al 2019]. The process of making Geopolymers is same as that of conventional concrete except the ingredients.

The demand for the natural river sand is increasing day by day due to increase in the construction activities. Manufactured sand can be used as the alternative without compromising the properties. Reports on geopolymer concrete with complete replacement with M Sand produced encouraging results (Sakthidoss and Senniappan, 2019). The use of Manufacturing Sand in the concrete contributes to the strength due to its better gradationDemolition waste and other industrial by products have high potential to be used as coarse aggregate in making quality concrete, all of which were once considered wastes and dumped in landfill. Recycled water may also be sued in place of potable water in making concrete. Thus all ingredients can be replaced by non-traditional materials.

Geopolymer concrete is an environment friendly and popular sustainable material which has a potential to replace conventional concrete (Duxson et.al. 2007). It has good resistivity against acids, sulphates and high temperature with low chloride penetration (Srividya i et.al. 2012 and Geraldes, et al).

Experimental results have shown that higher the ratio of sodium silicate to sodium hydroxide by mass, higher the compressive strength of the geopolymer concrete (Rangan and Hardijito, 2005, Rajmane and Sabitha). Ambily et.al. 2012, Ambily et.al. 2011. Rajamane, 2006 concluded that light weight aggregate based geopolymer has a compressive strength more than 50 MPa at 28 days. Crushed granite aggregates based geopolymer concrete exhibits more strength about 45 MPa at one day.

The effects of shape and texture of fine aggregate are much more important than the effects of coarse aggregate. It could lead to improvements of the strength of the concrete due to better interlocking between the particles (Donza et.al. 2002). Though, angular fine aggregate produces mortar of lower workability than spherical sand for the same water content (Jamkar et.al. 2004). The mechanical and durability properties of the concrete are reported to be considerably improved by using manufactured sand (Goncalves et.al. 2007 and Donza et.al. 2002). Manufactured sand contains high fines content with less amount of silt and clay content (Dilek et.al. 2006).

Coarse aggregate, after demolition, is converted as recycled aggregate. There are many reasons to reuse them (Oikonomou et.al. 2004). Recycled aggregates are suitable for non-structural concrete applications. It can be applied in producing normal

structural concrete with fly ash (Rao et.al. 2005).

Though there is good amount of research reported on ingredients, properties and applications of Geopolymers, there is no attempt made to prepare eco-efficient Geopolymer composites using alternative ingredients all together without compromising the properties. The research reported in this paper addresses this.

1.1 Materials and Methods

Low calcium ASTM Class-F fly ash and ground granulated blast furnace slag (GGBS) were used in the ratio of 60:40 as binders. The specific gravity of fly ash and ground granulated blast furnace slag were 2.40 and 2.90 respectively. Natural sand and manufactured sand were used fine aggregates. The specific gravity of manufactured sand and natural sand were 2.61 and 2.6 respectively. The fineness modulus of natural sand and manufactured sand were found to be 2.9 and 3.45 respectively. Both types of sands fall in zone-II [?]. The natural coarse aggregate which were used in this research paper had specific gravity 2.63. The fineness modulus was found to be 3.38. The recycled aggregate which were used in the research were prepared from the debris of the demolition waste which were procured locally. The maximum size of the recycled coarse aggregates was 20 mm. The specific gravity and the water absorption was found to be 2.38 and 3.60 % respectively.

Recycled water was used in this research having Ph of 7.6 with total suspended solids 20 mg/l. Alkaline solution of molarity 12 was used prepared by dissolving sodium hydroxide flakes. The ratio of sodium silicate to sodium hydroxide was maintained at 2.5.

Currently no standardized methods of mix design for geopolymer concrete are available. For standard concrete M25 grade was designed using IS 10262:2009 for 100 mm slump. The mix ratio was 1:1.8:2.97. The final mix proportions are 236.4 kg of fly ash, 157.6 kg f GGBS, fine aggregates of 709.2 kg and coarse aggregate of 1170.2kg per one m3 of concrete.

The fly ash, GGBS, M-sand and recycled aggregates were first mixed thoroughly in dry condition and then alkali solution was added to prepare geopolymer concrete. The ratio of alkali solution to fly ash, GGBS is 0.5 to 0.7 to maintain the workability at 100±10 mm. The geopolymer concrete was placed in 150 mm cube, cylinder of diameter 150 mm, and beam of 100X100X500 mm.

Geopolymer mortar was also prepared with natural sand and M-sand. Fly ash and GGBS to fine aggregate ratio was 1:6. For geopolymer mortar and cement mortar flow test, compressive strength and bond strength test were conducted. Geopolymer mortar was used as masonry mortar of thickness 15 mm to assemble the geopolymer blocks and tested for bond shear strength.

1.2 Results and discussion

In this section, discussion is made on geopolymer concrete and mortar.

1.2.1 Geopolymer Concrete

The compressive, split tensile and shear strength of different concrete mixes are shown in Figures 1. The following convention is used for better understanding.

CC = Conventionl Concrete

GPC – NA = Geopolymer Concrete with natural aggreagtes

GPC- MS = Geopolymer Concrete with manufcatured sand

GPC-RCA = Geopolymer Concrete with recycled aggreagtes

GPC-MS-RCA – Geopolymer concrete with manufcatured sand and recycled aggregates

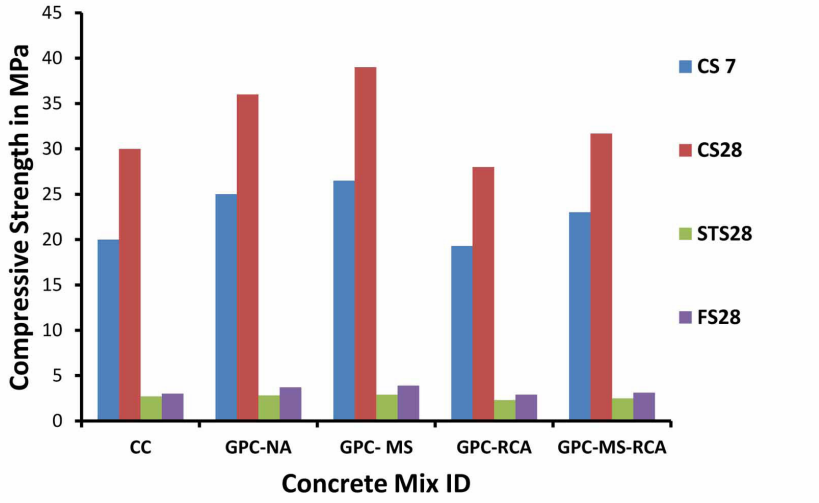


Fig. 1 Strength of various concrete mixes

The geopolymer concrete specimens which were cured in open air, developed a strength of 60-70% of the corresponding 28 days strength at 7 days. The compressive strength of all the types of geopolymer concretes were marginally higher compared to the conventional concrete, except geopolymer concrete with recycled aggregate. It may be due to the poor grain size distribution and weak transition zone in concrete with recycled aggregate. It can be seen that the split tensile strength is marginally higher for all

geopolymer concrete cylinder compared to the conventional concrete except the geopolymer concrete with recycled aggregate and geopolymer concrete with manufactured sand and recycled aggregate. The flexural strength of geopolymer concrete was marginally higher compared to conventional concrete.

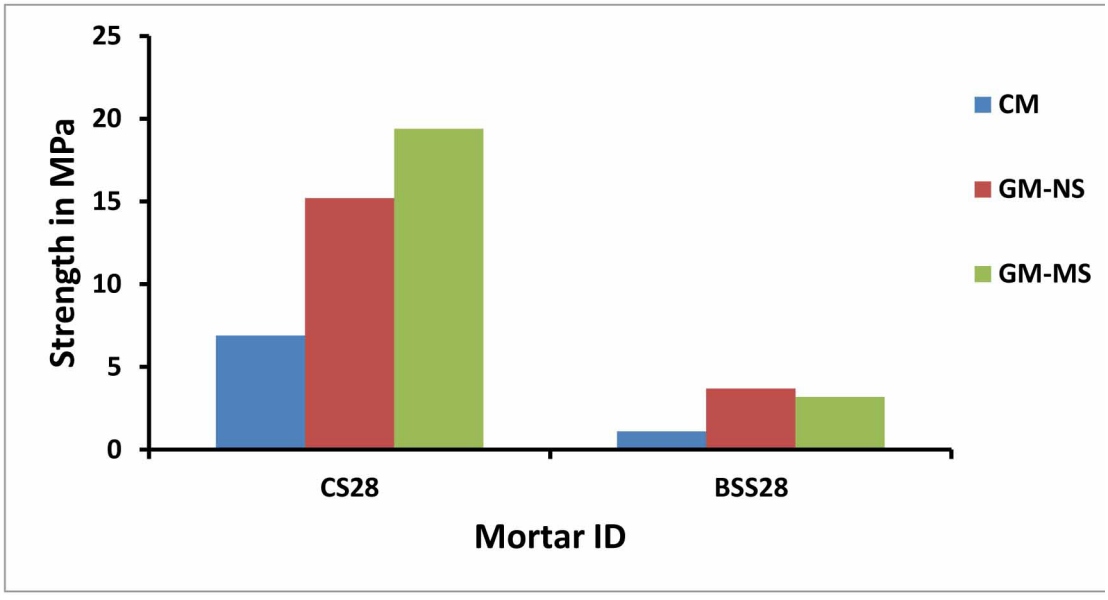
1.2.2 Mortar

The flow values of mortars are given in Table 1. It was found that for a flow of 100%, the water-to-cement ratio was 1.2, 1.25 and 1.4 for plain cement mortar, geopolymer mortar with natural sand and geopolymer mortar with manufactured sand respectively.

The compressive strength of different mortar at the age of 28 days is shown in Figure 2. It was interesting to note that geopolymer mortar with natural sand possess double the strength of cement mortar. The compressive strength of geopolymer mortar with manufactured sand was marginally higher compared to geopolymer mortar with natural sand. The bond shear strength was found to be higher in geopolymer mortar with natural sand and manufactured sand compared to plain cement mortar. Hence, this mortar can be recommended for masonry mortar in structural masonry.

Table 1. Flow values of mortar in mm

Conventional Cement mortar (CM)	Geopolymer mortar with natural sand (GM-NS)	Geopolymer mortar with M-sand (GM-MS)
169	166	164



1.3 Conclusions

Based on the present investigation, the following conclusions can be drawn.

- It is possible to prepare concrete by replacing all the ingredients by recycled/ waste material including the water.
- The compressive, split tensile and flexural strength was higher for geopolymer concrete compared to conventional concrete.
- Geopolymer mortar can be used as masonry mortar as it exhibits excellent properties.

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JSW Cement Limited & Sustainable Construction

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Abhijeet landage -Concrete technologist, JSW cement concrete laboratory Dolvi

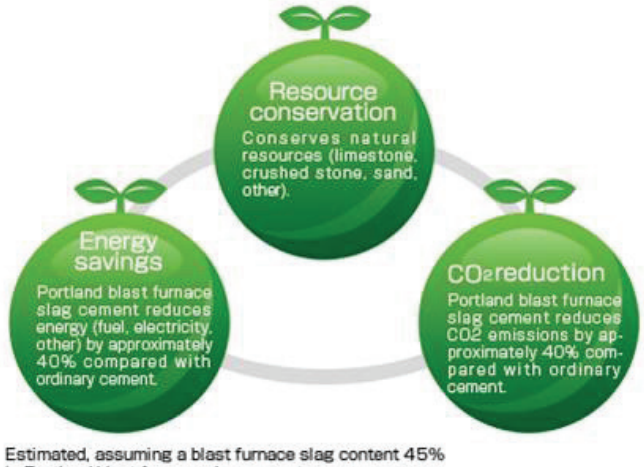
Key notes for JSW Green Products

As every one ton of Cement (OPC) produced, emits 0.96 ton of CO2, there is an urgent need to promote blending materials (ex GGBS &PSC) & screened slag, to achieve lower CO2 emissions, reduce green house gas effect, reduce exploitation of natural resources, use alternate industrial by product in production of concrete, alternate fuel usage etc.

Need of the hour is "Greener or Lesser Polluting Cements or cementitious products" by use of Industrial Byproducts such as Ground Granulated Blast Furnace Slag, which is otherwise a waste if not consumed

Slag is a non-metallic and non-hazardous by product of the Steel industry, having cementitious property. Using the above, cement industry utilities slag in cement manufacturing process & ground granulated blast furnace slag in concrete production.

The Portland slag cement &GGBFS, thus produced shall impart the following properties to concrete / other applications where cement is being used.



Estimated, assuming a blast furnace slag content 45% in Portland blast furnace slag cement

Also screened slag from the house of JSW cement is an excellent replacement of natural or manufactured /Crushed sand (replacement level is fully or partly, depending on design requirement). Screened slag is confirming to IS 383 and grants excellent strength & durability in concrete/mortar works, along with conservation of natural resources.

JSW Products (PSC/GGBS) as an Eco Friendly & Green product

- JSW provides products that are Sustainable & Environmental Friendly
- Pollution (Air, water & land) free environment ensures no adverse impacts on the health of nearby communities
- Utilization of slag and other by-products minimize burden on landfills
- Reduced virgin material usage
- Reduced fossil fuel usage
- Create sustainable sites using PSC /GGBS concrete
- Build Concrete with low embodied energy using PSC/GGBS

  Use Concrete that contains recycled materials.

  By use of PSC & Ground Granulated Blast Furnace Slag, Low carbon concrete can be produced, reducing carbon dioxide emission & at the same time quality of concrete is improved.

Advantages of JSW Greenproducts for end consumers

- Long term strength of concrete made with JSW green products are greater than concrete made with OPC & PPC cement
- Concrete made with JSW green products provides protection against corrosion of steel reinforcement
- Concrete made with JSW green products is almost impermeable
- Concrete cover remain intact , where JSW green products have been used
- Concrete made with JSW green products provides resistance to sea water attack in marine environment
- Concrete using JSW green products offers better resistance to sulphate, chloride, harmful gases attack & ingress of atmospheric water
- Usage of JSW green products ensures long design life /durability of structure with low maintenance cost
- Cracks are minimized and reduced in structures made with JSW green products

The following products are available from JSW Cement Ltd.

1. JSW Portland Slag Cement (JSWPSC)
2. JSW OPC
3. JSW Concreel HD
4. JSW Ground Granulated Blast furnace Slag (JSWGGBS)
5. Granulated Blast furnace Slag sand (GBS sand)

Environmental Product Declaration
of Average Ground Granulated Blast- Furnace Slag
JSW Cement Limited
ISO 14020:2006, ISO 14025:2006, ISO 14040:2006, ISO 14044:2006, EN 15804:2012, EN 16908:2017

EPD registration number:	S-P-01415
Publication date:	23-12-2019
Validity date:	22-12-2024
Geographical scope:	India

EPD®
THE INTERNATIONAL EPD® SYSTEM

ENVIRONMENTAL PRODUCT DECLARATION OF AVERAGE PSC CEMENT
ISO 14020:2006, ISO 14025:2006, ISO 14040:2006, ISO 14044:2006, EN 15804:2012, EN 16908:2017

JSW Cement

EPD registration number:	S-P-01414
Publication date:	2019-10-11
Validity date:	2024-10-10
Geographical scope:	India

EPD®
THE INTERNATIONAL EPD® SYSTEM

JSW Portland Slag Cement (PSC):

JSW PSC is a blended cement, wherein some portion of OPC is replaced with Ground granulated blast furnace slag(GGBFS), to make the structures long lasting& durable. GGBFS present in PSC helps in secondary hydration, producing more C-S-H gel in system for improved performance of concrete.

Some of the major advantages of JSW PSC are:

a) Reduced thermal cracks due to lower heat of hydration as compared to OPC

b) Reduced shrinkage cracks as compared to OPC, PPC

c) Improved workability and smooth finish

d) Improved cohesion

e) Better resistance against chemicals such as chlorides, sulphates and carbon dioxide

f) Higher long term strength

g) Improved durability

h) Green Product

Application of JSW PSC:

JSW PSC can be used in all types of civil engineering works – both structural and non structural applications. In fact it has got a wide spectrum of application compared to OPC. OPC is not suitable for works such as mass concrete, Industrial structures, marine structures, effluent and sewage treatment plants. Whereas PSC is ideal cement in these works and thus making it as all purpose cement.

JSW PSC is a sustainable material. As production of PSC ensures the conservation of natural resource (limestone), savings in energy in production process and limiting the emission of carbon dioxide, it is regarded as eco friendly cement or green cement.

The properties of PSC have been specified by BIS in,IS: 455-2015.CII – IGBC has certified, JSW PSC as a green product.

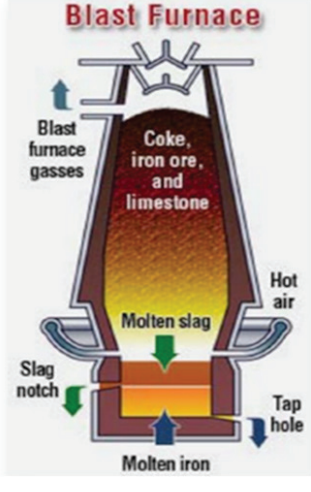
JSW Concreel HD:

JSW Concreel HD is a cement having high initial strength, high final strength, quick setting, superior cohesion, most durable, chemical resistant & is a green product. It conforms to IS: 455 – 2015.

Application of JSW Concreel HD:

JSW ConcreelHD is an ideal product for all kind of concreting works. However, Concreel HD can be used right from foundation to plastering.

JSW Ground Granulated Blast Furnace Slag (GGBS):



Slagis byproduct from steel plant,which is obtained from blastfurnace,during the separation of ironfrom iron ore. The process of granulatingof the slag involves, cooling of molten slag through high-pressure water jets. This rapidly quenches the slag and forms granular particles. The resulting granular material comprises around 95%, non-crystalline calcium-alumino silicates. The granulated slag is further processed by drying and then grinding in a vertical roller mill or rotating ball mill to a very fine powder, which is called GGBS.

The benefits, application and performance of GGBS are same as that of PSC. In case of PSC, predetermined dosage of GGBS is added,where as GGBS separately combined with OPC, offers flexibility of using,any particular dosage depending on the choice of the user.

Some of the major advantages of JSW GGBS concrete, as compared to pure OPC concrete or fly ash based concrete are given below:

a) Reduced thermal cracks due to lower heat of hydration

b) Reduced shrinkage cracks

c) Improved workability and smooth finish

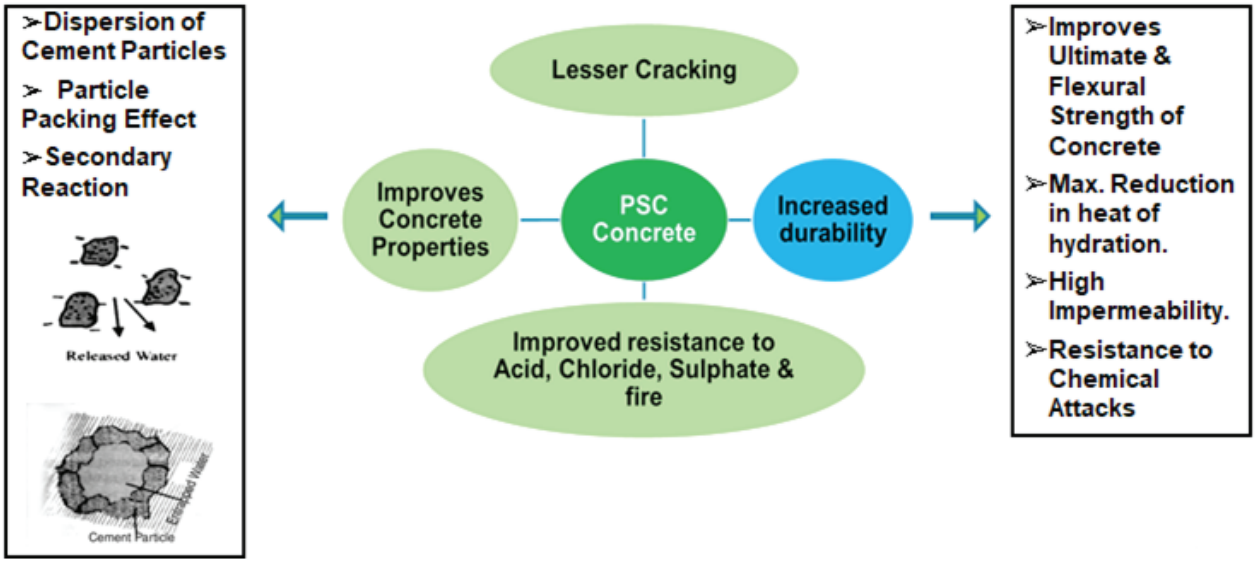
d) Improved cohesion

e) Better resistance against chemicals such as chlorides, sulphates and carbon dioxide

f) Higher long term strength

g) Improved durability

JSW GGBS meets the requirements of IS:12089-1989. GGBS is also eco-friendly product .

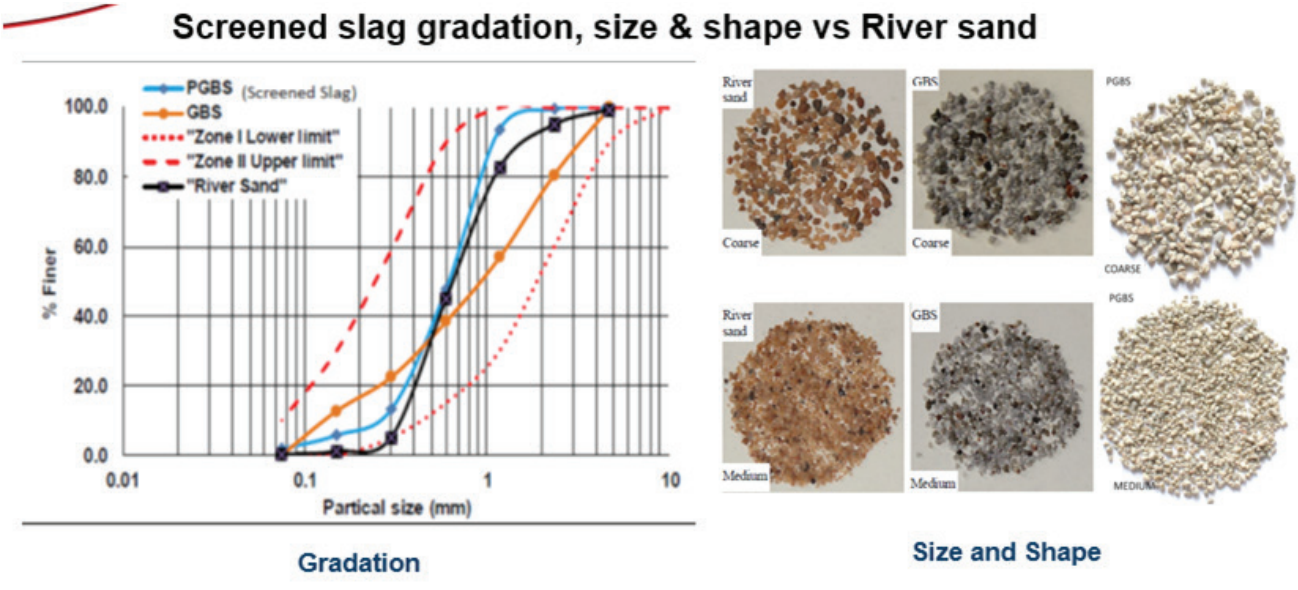


Application of JSW GGBS:

JSW GGBS can be used as partial replacement to OPC Cement in concrete production at RMC batching plants and Site batching plants.

JSW Granulated Blast furnace Slag sand (GBS sand) :

Fine aggregates are an integral part of mortar,concrete, plaster. River sand are regarded as idealfine aggregates. During recent years due to non-availability of good quality river sand, crushed rock fines (CRF), are being used as fine aggregates. However, CRF has some limitations such as– lack of moisture retention, making the mix non cohesive/harsh and hashigher water demand



GBS sand is an alternate to river sand as well as CRF. Slag obtained from blast furnace of steel plant is in the form of granules and looks like river sand, butis little greyish in colour. It is an inert material and is suitable for concrete and mortar, and can replace natural sand or CRF, up to a certain percentage (subject to field trials). The method of application of GBS sand is same as that of river sand / CRF. GBS sand had been tested, both in India and Internationally, and found to be suitable to be used, in mortar and concrete.

GBS Sand is superior to river sand because the latter contains fossils and other irregular particles like clay and silt that affects quality and durability. Also dredging of river sand is not eco friendly.

As use of GBS helps to maintain harmony with our ecology – no quarrying, avoiding the depletion of natural resource and savings in energy in crushing of the rocks. Like other products of JSW cement, GBS Sand is also aneco-friendly product.JSW Slag sand meets all the requirement of IS:383-2015.

Application of JSW GBSsand:

As replacement of natural sand or CRF in concrete & mortar

RECOGNISED BY THE GOVERNMENT OF KARNATAKA

Gopalan College of Engineering & Management

Approved by AICTE, New Delhi
Affiliated to VTU, Belagavi, Karnataka
2(f) status from UGC

Gopalan School of Architecture & Planning

Approved by, COA
Affiliated to VTU, Belagavi, Karnataka

WHITEFIELD, BANGALORE - 560048

080-42229748 ; +91-9980947177

www. gopalancolleges.com
gcem@gopalancolleges.com
gsap@gopalancolleges.com
admissionofficer@gopalancolleges.com

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- Aeronautical
- Computer Science
- Civil
- Electronics & Communication
- Mechanical

GSAP Programmes (UG & PG)

- Bachelor of Architecture (B.Arch)
- Master of Architecture in Construction Project (M.Arch)

We are the shapers of great minds and honorable values.

Shaping Minds
— Since 2010 —

Why US ?

01 Latest, Advanced & High Tech Labs.

02 Internships and Placements in our own companies (under Gopalan Enterprises) for all branches.

03 Collaboration with Industries for Training, Internships and Placements across all branches.

04 Best campus placement records. Highest package offered 14 lakhs PA 2020 batch.

05 Highly Qualified Faculties with Industry experience, at an average experience of 10 years. Minimum 2 Phd's in every department.

06 Foreign University Tie-up. Student Exchange Programmes

07 University Recognized Research Centre to offer Ph.D. in CS, Civil, EC & Mech Engineering

08 Transportation fleet covering major locations around the college.

09 Sports, Hobby, & Technical Clubs.

10 Education Loan Assistance.

11 In-House Medical Assistance.

12 Hostel with Organic Food, Wi-fi, Security, Separate Ladies Hostel, 24/7 Power Supply with Backup, Washing machines on every floor, Hot water.

13 CCTV Cameras and In-house Security 24/7 all around the Campus.

COMPANY PROFILE

Company Name	JSW Cement Ltd
Mailing Address	3rd Floor, JSW Centre, Bandra Kurla Complex, Bandra (East), Mumbai – 400051 | Maharashtra | India
Name	Lopamudra Sengupta
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Email	Lopamudra.sengupta@jsw.in
Contact Details	08886220262
Website URL	https://www.jswcement.in

Write about company :

JSW Cement aims to continue development of India with the use of its environment-friendly sustainable technologies. JSW Cement holds the potential to contribute to creating a self-reliant India by laying the foundation of the Indian development story with its world-class cement.

JSW Cement has its plants at Vijayanagar in Karnataka, Nandyal in Andhra Pradesh, Dolvi in Maharashtra, Shiva Works in Odisha and Salboni in West Bengal. All of these plants utilise the by-products produced by the steel industry to manufacture green cement. Despite of entering the industry late, JSW Cement with a capacity to produce 14 MTPA tons per year, is swiftly becoming a force to reckon with. JSW cement has a 3000 TPD Cement Clinker Production line in Emirates of Fujairah (UAE)

JSW Cement Ltd has the products- Portland Slag Cement, Portland composite Cement, Ground Granulated Blast Furnace Slag, Ordinary Portland cement and Screened Slag.

JSW Screened Slag confirms IS 383-2015, JSW Screened slag is a replacement of fine aggregate. Also Screened Slag is a green product.

JSW Cement Ltd is GreenPro certified organization for its product- Portland Slag Cement, Portland composite Cement and Ground Granulated Blast Furnace Slag. JSW Cement has Environment Product Declaration –EPD for Portland Slag Cement and Ground Granulated Blast furnace Slag.

1-GreenPro Certificate

a. Portland Slag Cement
- Nandyal Plant – GPJSW15001
- Dolvi Plant – GPJSW15001
- Vijaynagar Plant – GPJSW15001
- Salboni Plant -GPJSW15001

b. Portland composite cement
- Vijaynagar plant – GPJSW15002

C. Ground Granulated Blast Furnace Slag
- Nandyal Plant-GPJSW26002
- Dolvi Plant GPJSW26002
- Vijaynagar Plant –GPJSW26002

2-Environment product declaration
- Portland Slag cement - S-P-01414
- GGBS -S-P-01415

Company Name	Fosroc Chemicals India Private Limited
Mailing Address	Embassy Point No 150, 2nd Floor, Infantry Road, Bangalore – 560 001, India
Name	Mr. B N. Chandrashekar
Designation	General Manager
Email	Email : Chandrashekhar.Nagarajaiah@Fosroc.com
Contact Details	Contact Details : +91-80-42521900
Website URL	Website URL : www.fosroc.com

Write about company :
Fosroc Chemicals (India) Limited is a division of worldwide JMH Group. For over 50 years, Fosroc has developed intellectual properties in specialised products and services that are acknowledge being the cutting edge of construction technology.

Fosroc product portfolio:

Cement and Concrete Technology	Finishes	Barriers	Repair and remediation
Cement Additives	Industrial Flooring	Waterproofing	Concrete Repair Mortar
Admixture – SNF and PCE based	Heavy duty flow applied flooring	Joint Sealants	Crack Injection Resins
Corrosion Inhibitors	Surface Coating	Membrane Waterproofing	Corrosion Control
Surface Treatment Curing compound and release agents.	Protective Coating	Liquid applied, food grade certified waterproofing	Micro-concrete and Under water repairs
Grouts and Anchors Epoxy and cement based	Breathable protective coating	Pre-applied and spray applied robust water proofing system	Spray applied structural grade mortars FRP laminates and wraps

Fosroc is an ISO 9001: 2000 certified company which ensures that the quality of all products and service and the level of customer satisfaction are on par with highest standards in the concrete industry.

Company Name	M/s. Asian Paints Limited
Mailing Address	4th Floor West Wing || Kalpataru Synergy|| Santacruz (E)|| Mumbai-400 055
Name	Mr. Praveen Madipati
Designation	Head of Specifications - Waterproofing & CC
Email	praveen.madipati@asianpaints.com
	tejas.shah@asianpaints.com
Contact Details	M: +91 9686602186, Tel: 022-6218 1437
Website URL	https://www.asianpaints.com

ENQUIRE NOW

Painting your home is exciting, but choosing the right colours, products, and house painters while ensuring your family's safety can be a huge task. That's where we come in with our aim to make home painting a safe and great experience! With Asian Paints Safe Painting Services, re-imagine your home as a huge canvas.

Introducing Quick Home makeover - Getting your home revamped in just 7 days. Hard to believe? Not with Asian Paints Safe Painting Service. A quick makeover service, where the state-of-the-art products come together with the safest painting service, to give you a hassle free experience and a dream home – all in just 7 days!

Company Name	M/s. ULTRAFINE MINERAL & ADMIXTURES PVT. LTD.
Mailing Address	
Name	HARSHITHA S
Designation	TECHNO-COMMERCIAL & MARKETING
Email	harshitha.s@ultrafine.in
Contact Details	9739990219
Website URL	

Write about company :

Company Name	MRG-Composites India
Mailing Address	Survey No.236, Kishan cement gate, NH-27, Shapar – 360024, Rajkot, Gujarat
Name	Mr. Neel Vaya
Designation	General Manager
Email	india@mrg-composites.com
Contact Details	+91 96598 59896, +91 74051 69976, +91 88660 89839
Website URL	www.mrg-composites.com

Write about company :

JMrg composites India is a manufacturer of GFRP bars in India. GFRP bars are a substitute to the regular TMT bars. Our composite rebar (GFRP) are stronger, lighter, cheaper than the TMT bars used in construction.

Company Name	Nuvoco Vistas Corp. Ltd.
Mailing Address	Equinox Business Park. Tower-3, East Wing, 4th Floor, Off Bandra Kurla Complex, Kurla-West. Mumbai – 400070
Name	Mr. Indranil Banerjee, Mr. Aashai Singhal
Designation	General Manager - Marketing
Email	indranil.banerjee@nuvoco.com, aashai.singhal@nuvoco.com
Contact Details	+91-99675 95258 / 9410888828
Website URL	www.nuvoco.in

Write about company :

Nuvoco Vistas Corp. Ltd, a Nirma Group company, is a leading manufacturer and retailer of building materials in India with a vision to 'Build a Safer, Smarter and Sustainable World'. We started operations in India in 1999 via acquisitions, and since then have emerged as one of the major players in India. Nuvoco is one of the top cement manufacturers in India, and the leading player in the East following the acquisition of Nu Vista Limited (formerly Emami Cement Limited); offering high-performing, premium, blended cement variants.

Our diversified business portfolio includes

Cement : Our cement is among the foremost in the industry and are known for its world-class innovations (that comes from our in-house Construction Development and Innovation Centre (CDIC) based in Mumbai), best BIS standard ratings and use of premium quality raw material offering premium products like Concreto, Duraguard, Nirmax and Infracem.

Ready-Mix Concrete (RMX)

Our RMX business enjoys pan-India presence offering specialised products like Artiste and InstaMix being proud contributors to the landmark projects like Lodha World One, Amritsar Entry Gate, and the Metros (Delhi, Jaipur, Noida and Mumbai).

Through our NABL-accredited Construction Development and Innovation Centre (CDIC) based in Mumbai, we identify latent gaps in the industry and offer customised solutions to our customers.

Modern Building Materials (MBM)

Our Modern Building Materials (MBM) product range under the Zero M and InstaMix brands comprises construction chemicals, multipurpose bonding and waterproofing agents, Wall Putty, Tile Adhesive, Ready Mix Dry Plaster and Cover Blocks.

Company Name	Hilti (India) Pvt Ltd.
Mailing Address	6th Floor | Building 8 | Tower C | DLF Cyber City | Phase-II | Gurugram – 122002
Name	Nandeesh Palagatti
Designation	Head Engineering
Email	Nandeesh.palagatti@hilti.com
Contact Details	9741559000
Website URL	https://www.hilti.in/

Write about company :
JHilti is one of the global leading companies in providing innovative construction solutions.

Hilti's innovative products and systems solution i.e. Anchor Systems, Firestop System, Electric Tools & Accessories, Direct Fastening & Screw Fastening, Installation System & Fire-stop Systems, Software & Services helps to achieve astonishing feats – from the lifeline Metro to the state of the art Airports.

Hilti is committed to provide solutions to its customers with it's dedicated specialists engineers across nation and build a better future.

Hilti Toll Free No 1-800-102-6400

https://www.hilti.in/

ANJALI CONSTRUCTION

Anjali construction established in the year 2013 in Chennai (Madras), Tamil Nadu state and having its Branch Office in Bangalore, Karnataka. Anjali Construction is Pioneer in Concrete Flooring Industry in India and provide the most durable, Optimized and Customized flooring solutions using the best of the latest flooring technologies available in the world.

Anjali Construction offers a wide range of Flooring Services across the Country. We are one of the few Flooring Companies in India who has the required infrastructure and expertise in doing Concrete Flooring Works.

Anjali Construction provides a full range of high quality and cost-effective flooring construction services for Industrial Floors, Warehouse floors for smart logistics centers, large retail centers and the related fields which require high performance floors with very strict tolerances. The Flooring Services that Anjali Construction offers are as follows;

OUR SERVICES

- FM-1, FM-2 & FM-3, (Class Flooring) as per TR-34 standard specification using LASER SCREED MACHINES.
- Concrete Floor Densification and Polishing
- Vacuum Dewatering Flooring
- TREMIX Concrete Flooring
- Concrete Floor Repair & Rehabilitation works
- Epoxy Coating and Dust Proofing
- Water Proofing
- Dust Proofing

Anjali Construction has best of the equipment available in the world for Warehouse Flooring works. To quote an example, we have imported Laser Screed Machines from Somero, USA. In addition to the Equipment, we have Skilled & Committed Man Power for execution of Flooring works.

Head Office :

ANJALI CONSTRUCTION
Concrete Flooring Solutions

No.4, Sivan Kovil Street, Thaiyur,
Kelambakkam, Chennai – 603 103.
Mob: +91 9952086498 / +91 86675 37073
Email : md@anjaliconstruction.com

Branch Office :

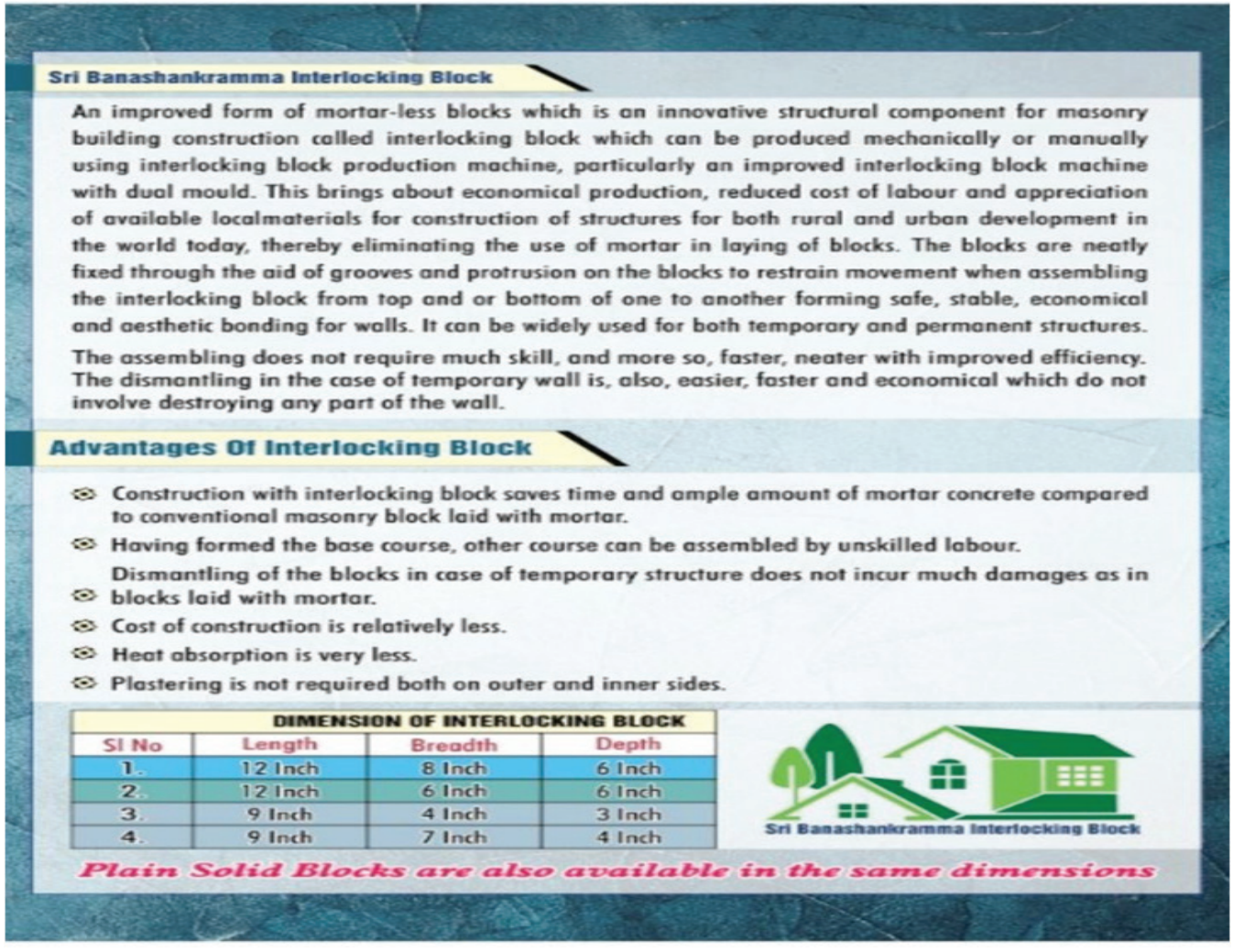
Bangalore : No.70, Near Bagaluru Police station
Bagaluru, Bangalore – 562149
Mob: +91 9845697663 / +91 7348875558
Email : info@anjaliconstruction.com

Hyderabad : No.202, VDR Residency,
Opp Hotel tulips Grand, Peerzadiguda,
Meddipally, Hyderabad – 500092
Email : marketing@anjaliconstruction.com

www.anjaliconstruction.com

Company Name	M/s. Sri Banashankaramma Interlocking Block.
Mailing Address	Thallaghattapura Post No 582 Survey No 15/7 Holiday Village Road, Kanakapura Main Road, Bangalore. Karnataka, India.
Name	Mr. Shivakumar & Mr Darshan BS
Designation	
Email	dgowda030@gmail.com
Contact Details	Mobile: +91 7019733682 / 9480613670 / 9448385124
Website URL	https://sbinterlockingblocks.com

Write about company :



Company Name	M/s. S.K. STEELTECH PRIVATE LIMITED
Mailing Address	Corporate Office, 162/A/34/2, 2nd Main Road, Industrial Town, Rajajinagara, 6th block, Bangalore -560044.
Name	Mr. K George Prabhu
Designation	Director - S.K. STEELTECH PRIVATE LIMITED
Email	prabhu@sksupertmt.com
	Contact Details : +91-80-42521900
Contact Details	Mobile: +91 7760968202, Tel. 080 2330 7202
Website URL	www.sksupertmt.com

Write about company :

The foundation of this quality TMT Steel was laid down in the year 1987, by Shri. S. Kulandaisamy along with a team of dedicated professionals, with a vision and commitment to provide the utmost quality products that meets the requirements of structural engineers varied needs of construction.

The journey of SK Super TMT started with the establishment of its melting division to manufacture high quality ISI graded steel billets with perfect chemical composition and supply to various steel Re-Rolling Industries. After establishing itself in the industry as a trusted brand and manufacturer of pure billets for over two decades, the group set foot into manufacturing TMT as part of their backward integration plan.

With quality control from the source of raw material, SK Super TMT became the most preferred choice of structural engineers. Today as part of part of technology upgrading, SK Super TMT introduced Integrated Rolling Technology, a revolutionary and eco-friendly technology for manufacturing high quality TMT steel to meet the quality requirements of the structural engineers in the Karnataka.

PRODUCTS:

FE 550 Grade Thermo Mechanically Treated Bars confirming to IS Standard.

FE 600 Grade Thermo Mechanically Treated Bars confirming to IS Standard.

With the World Class Infrastructure and focus on at most quality control, SK Super TMT is Synonymous with the highest quality standards in manufacturing; with a thorough knowledge of the product and continuous efforts in research and development, we have redefined the technology of manufacturing steel with respect to quality, strength and purity.

PRODUCT FEATURES: Xtra Grip: - SK Super TMT's patented robo-rib pattern, ensures highest AR values, maximum bonding with concrete. Elongation: - @18% the single most important factor, that determines safety of building construction. The elongation after yield strength and before ultimate tensile strength phase is 18% min. Earth Quake Resistant: - The Ideal combination of strength and flexibility offers the safest plan against Earthquakes, UTS: YS ratio is more than 1.15 min.

The brand has taken the responsibility of educating the consumer and the influencers about the best construction practices, trends and the need for right construction steel. Further the brand has created a greater awareness amongst the consumers about the need for good quality steel by awakening the thought that. "You build your home once, it's your hard earned money and a dream of your parents and a strong foundation for your children's future, hence choose the right steel".

Company Name	ELEMATIC INDIA PVT. LTD.
Mailing Address	H-38, 1st Floor, Bali Nagar, New Delhi 110015, India
Name	Mr. Shridhar Rao, B.E, M.B.A
Designation	Sales Head - India
Email	Shridhar.Rao@elematic.com
	9741559000
Contact Details	Mobile: +91 9591847722 Tel. +91 (11)4 576 9837, 4 732 0220
Website URL	http://www.elematic.com

Write about company :

ELEMATIC India Pvt. Ltd. is a Finland based company offering Precast Technology.

Elematic has footprint in more than 100 countries and has delivered more than 3600 installations of Precast Plant and Machinery

In India Elematic active since 2007, offering complete services for implementing Precast Technology and has 32 active plants operational.

Elematic offers complete handholding and services in implementing Precast Technology;

The Technology available is used in manufacturing of the following Precast Elements

Pre stressed Hollow core slab and solid slab on long line production system

Precast wall and slab production on Carousal system

Precast column and Beam production

Precast Staircase and Lift shafts

Partition wall Technology using Acotec plant

Elematic is a Technology partner and can associate from Design stage to implementation of Precast Technology.

Elematic has the capacity to deliver the full range of Precast Technology and holds 450 patents that allow you to manufacture building structures that allow faster and economical construction that we call as “Smart Evolution”

Company Name	Putzmeister Concrete Machines Private Limited
Mailing Address	Plot N-IV, Phase 4, Verna Industrial estate Salcette- Goa 403722, India
Name	Mr. Wilfried Theissen
Designation	Managing Director
Email	Marketing.india@putzmeister.com
Contact Details	+91 9158534123
Website URL	www.putzmeister.com

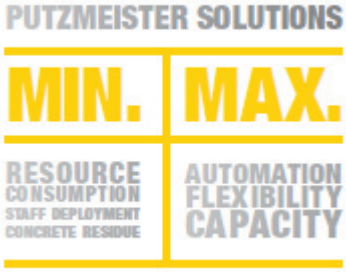
Write about company :

Putzmeister is a world leading solution provider for pumping, mixing and placing concrete, motor and industrial solids.

We provide world class products and services, setting the standards for quality through continuous and significant investment in research and development. We provide our clients with advice and support ranging from the right choice of machines to be used for a construction project to engineering solutions. Our machines are used for a range of applications including civil engineering, mining, tunneling, precast factories, large-scale industrial projects and power stations. We handle all types of projects, irrespective of scale or remoteness of location.

With over 20 subsidiaries worldwide and manufacturing units across the globe, we combine top-end German engineering, technology, expertise and high manufacturing standards with locally relevant requirements to provide a comprehensive solutions package.

For pre-cast applications Putzmeister offers solutions to produce, transport and place concrete during the manufacture of precast elements. We also offer post-erection mechanized solutions for thixotropic filling, grouting, plastering and concrete repair.



Our solutions are engineered to ensure less material wastage, reduced manpower while delivering increased output.

Want more? Even better prospects await you with state-of-the-art systems that offer maximum flexibility with minimal costs and personnel capacities.

What do you need? Clever solutions from a partner with decades of experience and process know-how in concrete.

To learn more about how we can support you, please meet the Putzmeister team at Stall #8.

Company Name	M/s. Protect Infrastructure Systems Pvt Ltd (Waterproofing and Waste Management)
Mailing Address	# 44, 3rd Floor, K.R.Road, Tata Silk Farm, Next to Garadi Apartments, Above Axis Bank, Basavanagudi Bangalore 560 004
Name	Dr. (HC) S.B Raghunath
Designation	Founder - Director
Email	psgpl2012@gmail.com
	9741559000
Contact Details	9945854043 / 9108460043
Website URL	Website: http://www.protectgroup.in, https://youtu.be/4CyPxw7nzKA

Write about company :

We are company engaged in providing engineering solutions in field of coatings, power, civil, water, renewable energy, processed foods, hygienic products. Under civil we have waterproofing compounds like WATERSHIELD a composite polymer based material working on Viking action using water as carrier. PERFECTCOAT is a series based on coaltar, PU, EPOXY, silicone, ceramic and cementatious. Underwater epoxies, cold-welding compounds, high temperature version cements, concrete stitching and bandaging materials, precast materials like tiles, blocks precasts user defined and normal ones.

Under water we have RO, STP, DM, ETP, DESAL units under brand name JALSHAKTHI.

Under RE we have solar powered LED and heating units and also application development clinic under brand name RAVISHAKTHI. Hygienic products is non phenolic/acidic/detergent based cleaning material that can be used to clean plastic, glass, wood, automobiles, facades Under brand name PRISTINE.

Underbrand name SUSWAD we have energized, vitaminaised, flavoured RO water and maize based products like chakkali, doughnuts, laddos, holige idly, dosa, vada.

Our clientele carries L&T, R M Z, BRIGADES, SHOBA DEVELOPERS, PURUVANKARA, MES, CPWD,, Namma metro, LIC, KFC, Tachobel, KNK Consructions, Kennametal, Hosmat Hospital, Coffee Board to name a few.

Company Name	CONCRIA FLOOR SOLUTIONS PVT.LTD
Mailing Address	A-103 Venkatesh Nisarg Apartment, Vadagaon BK PUNE-411041
Name	Mr. Shailendra Patne
Designation	Sales and Support Representative
Email	Sales.w@concria.com, Office.india@concria.com, vivek@concria.com
	Contact Details : +91-80-42521900
Contact Details	8407937575
Website URL	india@concria.com

Write about company :

Concria Floor Solutions Private Limited is a Private incorporated on 28 November 2018. It is classified as Subsidiary of Foreign Company and is registered at Registrar of Companies, Pune. Its authorized share capital is Rs. 100,000 and its paid up capital is Rs. 100,000. It is inolved in Business activities n.e.c.

Concria Floor Solutions Private Limited's Annual General Meeting (AGM) was last held on 23 September 2019 and as per records from Ministry of Corporate Affairs (MCA), its balance sheet was last filed on 31 March 2019.

CONCRIA OPTIMAL SLAB™ – SUPERB CONCRETE SURFACE

Polishable and decorative dry shake topping: Can you imagine a dry shake hardener which looks like a terrazzo or a pure white concrete floor? Concria has made it a reality. Revolutionary Concria OPTIMAL SLAB™ is a polishable, extra depth dry shake topping. Time is money. Concria OPTIMAL SLAB™ topping is applied on freshly laid concrete like any other dry shake. It is polishable in just 7 days after casting. With Concria™ FAST power trowel grinding and polishing system, you can even polish up to 3 000 m² in a day.

Harder than granite – better than concrete: Thicker topping with minimum crazing and efflorescence - Patent pending Concria OPTIMAL SLAB™'s thicker and denser surface layer gives different design options which are made for extreme high traffic. Concria OPTIMAL SLAB™ is made to you only by Certified Concria™ Contractors with the assistance of Concria™ Team Professionals. You get polished colorful or terrazzo topping budget-friendly and super-fast.

Fields of application

Stores, big-box retailers, shopping centers

Schools, universities

Car parks, warehouses

Factories, logistic centers, heavy industry

Main benefits:

Superfast - flooring is ready in 14 days from casting

Budget-friendly decorative floor - polished terrazzo or cloud-like dry shake topping

High quality - thicker topping with minimum crazing and efflorescence

Harder than granite - Wear resistance is A3 on the Böhme scale

Company Name	M/s. Angel Constructions
Mailing Address	College Circle, Puranik Building, Vidyagiri, Bagalkot - 587102.
Name	P John Francis
Designation	Proprietor
Email	info@angelconstructions.in
Contact Details	9686501021 / 9448110826
Website URL	www.angelconstructions.in

Write about company :

Angel Constructions Established in 2002. We are doing the Construction works in Karnataka state. We create and cares for the essential assets that make our society work, assets that play an important part in people's daily lives. We establish numerous industrial, commercial, residential homes, school buildings, colleges, hospitals in the different parts of the Karnataka state. Through the use of the newest technology coupled with 19 years of experience in the construction business, we are assuring you of excellent workmanship from start to completion of the project. assured that the quality and service that we render will be suited to your needs and will meet your expectations.

Company Name	TECHNO SEAL
Mailing Address	No:457/D, 1st Cross, Ideal Homes Township, Rajarajeshwarinagara,Bengaluru-560098
Name	Er.Siddaraju.KM
Designation	Proprietor
Email	technosealindia@gmail.com, reachus@technoseal.in
Contact Details	080-28601452, 080-41215123, 9611221105, 9900960105
Website URL	www.technoseal.in

Write about company :

TECHNO SEAL was incorporated in the year 2010 and registered office in Bengaluru. The company is headed by Mr. K.M. Siddaraju who himself is a qualified civil Engineer with hands-on experience and thorough knowledge in the field of Structural rehabilitation, Soil stabilization, Epoxy and Polyurethane floorings, Waterproofing and construction aids systems. The company is engaged in offering Technical consultation and specialized services for concrete structures and buildings. The company has grown up in all the fields with a quality assurance from customer satisfaction. The company has got well experienced and qualified staff to cater the requirement of the Construction Industry.

TECHNO SEAL commenced its activities in the construction chemicals for more than a decade. The companywas formed after a huge experience of working on field and to deliver the best to the construction chemicalIndustry in all ways. To date the company has done a lot of reward winning work assigned to it with appreciation from contractors, builders, architects, consultants and owners from all section of the Construction industry.

TECHNICAL ADVISORS:

Mr. Nagesh V Hanagodu- M Tech IIT Bombay, Chief Technical Advisor

Mr. Yogananda MV- M Tech (C T), Technical Advisor- Concrete

Mr. Abhishek M Tech (Structure), Technical Advisor-Structural

Mr. Gopalakrishna E – BE(Civil), Technical – NDT and Structural Rehabilitation

OUR SERVICES ARE:Special Segment:

• Structural Rehabilitation • Soil Stabilization • Industrial Epoxy and Polyurethane Flooring

• Guniting / Shotcreting works • Injection Grouting- Cementation, Epoxy and Polyurethane

Waterproofing Services: • Basements and Retaining walls • Tunnels, Aqueducts and canals• Terrace and Podium slabs• Expansion joints, slab and wall cracks • Swimming Pools and water bodies

• Overhead water tanks / UG Sumps / STP Tanks • Planter box and Water Bodies

Why Us? : We are successfully catering to the growing demands of various sectors of construction industries due to our effective solutions. Some of the reasons which have made us the preferred choice of clients are mentioned below:

• Industry specific requirements / Transparent business dealings

• Timely execution / Low-cost high performance

AIM

The aim of the company is to provide the best quality products and services at the reasonable prices and in time delivery and timely execution

For more details, please visit our website: www.technoseal.in

Company Name	ARS Steels & Alloy International Pvt Ltd
Mailing Address	D - 109, L B R Complex, II nd Floor, Anna Nagar East,
CHENNAI - 600 102	P John Francis
Name	T.S Ragu
Designation	General Manager (Institutional Sales)
Email	ragu@arssteels.co.in
Contact Details	7550188555
Website URL	http://arsgroup.in/

Write about company :

One of the biggest players in the steel industry in Tamil Nadu, ARS Steel, an ISO 9001 and 14001 certified steel manufacturer, has one of the largest induction furnace-based Steel mills in the country. The company is quality focused and does not compromise when it comes to delivering high-quality and best-in-class TMT bars.

Further, ARS Steel, in 2009, increased its billet production by installing a new furnace, thereby increasing the total capacity of the furnace to 1,30,000 MTPA. It also increased the capacity of its rolling mill to 1,80,000 MTPA.

In the future, the company plans on expanding its present steel melting facility even further by putting up another 25 MT furnace by January 2020. Thus, ramping up billet production capacity to 2,50,000 MTPA and rolling mill capacity to 2,50,000 MTPA.

Keeping in mind the commitment it has to its country and her people, ARS Energy, established in August 2013, was started to enlighten lives. Already successfully running a 60 MW Captive Power Plant, the company plans on setting up a higher-capacity Power Plant, with the aim of building a nation that is self-sufficient in power generation

Company Name	Dalmia Cement (Bharat) Ltd
Mailing Address	Dalmia Cement (B) Ltd, 101, Embassy Square
	148, Infantry Road, Bengaluru 560001
	BENGALURU, KARNATAKA 560001
Name	Venkatram Reddy
Designation	Manager
Email	Reddy.venkatram@dalmiacement.com
Contact Details	Office: 080 - 40848383 / 41327677; Mob: 9900039184
Website URL	https://www.dalmiacement.com

Write about company :

Founded by JaidayalDalmia in 1939, Dalmia Cement is one of India's pioneering cement companies. Headquartered in New Delhi, the company operates as Dalmia Cement (Bharat) Ltd., which is in turn is a 100% subsidiary of Dalmia Bharat Ltd., listed on the National Stock Exchange and Bombay Stock Exchange (NSE: DALBHARAT; BOM: 542216).

It is a part of the Dalmia Bharat Group, one of India's most respected business conglomerates- the other businesses of which include Sugar and Refractory products.

Dalmia Cement's availability spans across 22 states and union territories, mainly in East, North East and Southern India, with selective presence in Uttar Pradesh and Maharashtra.

Company Name	WELDMESH MANUTURER'S ASSOCIATION
Mailing Address	S.no 513, Western India Wire Ind, Pokhran Road no 2, Opp. Maitri Garden, Thane, Maharashtra – 400 600
Name	Mr. Zakir Ahmed
Designation	Secretary
Email	econovasteel@gmail.com, info@skweldedmesh.com, weldmeshassociation.india@gmail.com, ragu@arssteels.co.in
Contact Details	99800-72775 / +91 9980 072 775, 7550188555
Website URL	www.weldedmesh.com

Write about company :

WMA (Weldmesh manufactures association in India), a non-profit body is committed to the ethical useage and growth of welded mesh industry in India.

With over 50+ manufacturing members located pan India& growing, we are the apex body for weldmesh related matters in India.

One of our objectives is to introduce & promote the use of reinforced weldmesh / WWR used in construction, having applications in floor slabs of warehouses as well as residential housing projects with the inclusion in shear walls

Do visit our website : www.weldedmesh.com to know more about us.

Email : weldmeshassociation.india@gmail.com

Company Name	M/s. FIBERCRETE (From the House of KALYANI POLYMERS PVT LTD)
Mailing Address	Survey no. 46/1, 11th KM, Off. Kanakapura Main Road, Doddakallasandra, Bangalore-560 062.
Name	Mr. B Chandrashekar Rao,
Designation	General Manager – SCM & BD
Email	sales@fibercrete.in
Contact Details	+91 98459 19650 / 080-2666 1287 / 1303
Website URL	www.kalyanipolymers.com

Write about company :

Kalyani Polymers was incorporated in 1995. This Company began its operation as a Extrusion specialist for Polypropylene & Polyolefin Polymers catering to Technical Textiles, Cable wrapping, Agripacking and other allied industries. In 2014 the MMCF (Micro & Macro Concrete Fibre) division was installed to cater to the fast developing Construction industry and other Technical textile products.

The ethos of our organization is based on achieving the greatest level of customer satisfaction by offering World class Fibers of International Quality at very economical prices due to indegeniousation of Raw Material and it's a 100 percent "MAKE IN INDIA" Products with a comprehensive Quality Control System of "ISO : 9001-2015" and "RHOS & REACH" compliancy.

We abide by the ethos for organization being "Customer's Satisfaction is our only Priority" in all our business dealings and thus offer value for money and quality products and competitive prices. We have grown with complete commitment and have carved a niche for ourselves as one of the leading and fastest growing suppliers of fibers and also Exporting all our products to North America, South America and European Countries.

FIBERCRETE - FF / MF (VIRGIN POLYPROPYLENE FIBRE) "NEO FIBRES FOR NEXT GENERATION CONCRETE" Polypropylene Fibrillated Fiber (FF) & Polypropylene Multifilament Fiber (MF) use in Construction Industry / Warehouse Floorings, Concrete Roads, RCC Beams, columns, Pre-casting, Waterproofing, Lintels, etc.,

Company Name	Talrak Construction Chemicals Pvt. Ltd
Mailing Address	No.37/2, Gowdanapalya, Subramanyapura Main Road, Bangalore - 560061
Name	M .N Ramesh
Designation	Managing Director
Email	mnramesh@talrak.co.in
Contact Details	9740030156
Website URL	www.talrak.co.in

Write about company :

Talrak Construction Chemicals Pvt Ltdwas established in 2014 by the promotors Mr. M.N Ramesh and Mr. AnandTalikoti who have technical and industrial experience of over 4 decades. We are equipped with a state-of-the-art liquid, resin and powder plant at Harohalli Industrial Area near Bangalore with a capability of producing high quality construction chemicals with a production capacity of 25,000 TPA. The production complies with the ISO-9001 industry standard to manufacture a wide range of products in the following product categories:

- Concrete Admixtures and surface treatments
- Dual shrinkage compensating free flow high strength cementitious grouts for grouting base plates and bolt pockets
- Non shrink Epoxy grouts and resin anchor products
- Repair and rehabilitation (Remedial Engineering) products
- High performance Industrial Floor toppings and coatings
- Ultra- High-Performance Concrete premix to produce concrete of M120 (120 MPa) and above – First time in Indian Market
- New generation Structural Strengthening products and systems

We also have a strategic Cooperation with KosterBauchemie AG of Germany which is one of the world renewed manufacturers of Waterproofing systems. We offer techno-commercial support for their products in India.

TALRAK not only manufactures world-class construction chemicals but also assists its clients with unique set of services such as

- Regular site visits
- End-to-End Technical Support
- Problem Identification
- Product Recommendation
- Application Methodology
- Applicator Support by our trained applicators. (Optional)
- Supervision of Application process
- Design support for Remedial Engineering projects.

Some of our Valuable Clients

and many more....

Company Name	M/s. SRI LAXMI WIRE NETTING
Mailing Address	4/1,N.R.Road 2nd Cross, New Bamboo Bazar, Road,Bangalore - 560002
Name	Lakshmi Pathi
Designation	Managing Partner
Email	slwnblr@gmail.com
Contact Details	9880063138, 6362911125, 08043365999
Website URL	Sri-laxmi-wire-netting.business.site

Write about company :

- We are experienced in this field since 2 decades.
- We can cater to your specific requirement of Wire Mesh & Allied Products.
- Wire Netting are unique products used in Segregation, Filteration, Protection, Reinforcement& Ventilation.
- Choose the wire craft from the range of products – Expertise Simplified.

Company Name	Ultrafine Mineral and Admixtures Pvt. ltd
Mailing Address	sales@ultrafine.in
Name	Navneet Nair
Designation	Business Manager South India
Email	Navneet.nair@ultrafine.in
Contact Details	7907814253
Website URL	www.ultrafine.in

Write about company :

Ultrafine Mineral and Admixtures Pvt. ltd is a TrueNorth group company having state of the art manufacturing facilities in Nagpur, which specialize in manufacturing and distribution of UltraFine™ additives for Concrete, grouts and high strength mortars.

We at Ultrafine Mineral and Admixtures Pvt. ltd are passionate about creating effective solutions for concrete and construction industry which are robust, cost effective and sustainable. With the right mix of enthusiastic people and highly competent team in R&D, Sales and Production company is set take a leading role in the industry segment.

ULTRAFINE MINERAL & ADMIXTURES enjoys a reputation of being one of the most efficient mineral additives manufacturers in India. Its environment protection measures are one of the best in the country. We have been at the forefront in setting high standards for plant and machinery, production, quality systems and services.

We provide cleaner and safer environment, save national resources like less embodied energy reduce the pollution and raw material hence less cement will be used & ensure clean air to breath reduction in carbon emission.

We are committed to achieve and maintain high standards of Health Safety & Environment in its manufacturing units and office and we believe they are crucial aspects of our operations. Beside the necessary legal compliances, our commitment to HSE demonstrates our value for Human life, Employee Morale and Professionalism.

Mr. Georg Dirk was the first one to introduce processed and ultrafine fly ash for the technical and economic benefit of the construction fraternity in India in the year 2000. Since then processed Fly Ash is being used for high performance concrete in mechanized batching plants for all prestigious projects.

Ultrafine Mineral & Admixtures Pvt. Ltd has joined hands with Mr. Georg Dirk who has licensed them to use the “Dirk” brand for processed and ultrafine fly ash naming it as “DIRK UltraPozzoTM” for western India.

Indian Concrete Institute - Karnataka Bangalore Centre

No-2, UVCE Alumni Association Building, K.R.Circle, Bangalore - 560 001.
icikbc@gmail.com. Website: icikbcbangalore.org
Contact No : 080 - 22224803

BECOME AN ICI - LIFE MEMBER TODAY
and
RE DISCOVER YOUR SELF

Membership Advantages :

INDIVIDUAL MEMBERSHIP

If you are a member of ICI, you become eligible for :

- Concessional delegation fee to participate in national and international events conducted by ICI.
- Access to technical papers of Associated Concrete Institutes.
- Receipt of quarterly ICI Journal which carries valuable technical articles.
- Receipt of monthly e-bulletin "ICI Update" to keep abreast of happenings in ICI.
- Publication of peer reviewed technical articles in ICI Journal.
- Publications of ICI at concessional cost.
- Access to ICI's reference library.

Above all, ICI events provide a unique platform to learn and share the best practices in making good concrete where sellers and buyers meet together

Please contact : **Mr. Pasha 8951607887** Tel : 080-22224803 email : icikbc@gmail.com

Dr. L. R. Manjunatha
Honorary Chairman
Bengaluru Centre

Dr. R L Ramesh
Honorary Secretary
Bengaluru Centre

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all it takes!

Specialist in Concrete Technology

Masters in Soil and Asphalt Compaction

Demolition & Pumps

Products and capabilities for every demand.

Wacker Neuson is a leading manufacturer of construction equipment with more than 50 affiliates, 150 sales and service stations and over 12,000 sales and service partners worldwide. We are your partner of choice in India

Wacker Neuson Equipment Pvt. Ltd.
12E, Sadaramangala Industrial Estate
Whitefield Road
Bengaluru 560048, India.
Tel.: +91 (0) 80 2841 2156 / 57
www.wackerneuson.com
Email: info.india@wackerneuson.com

Call us:

Bengaluru	:	+91 70220 09051
Bengaluru	:	+91 89714 35222
Bhopal	:	+91 99805 68940
Hyderabad	:	+91 81056 71688
Kolkata	:	+91 70220 09058
Mumbai	:	+91 70220 30725
New Delhi	:	+91 70220 09055
Pune	:	+91 70220 09057
Vadodara	:	+91 70220 09053

WACKER NEUSON
all it takes!

Application for Individual Membership

Indian Concrete Institute

No.201, First Floor, Ten Square, No.64, Jawaharlal Nehru Road,
Koyambedu, Chennai - 600 107, Phone : 044 - 24792602, 24795148
Email : ici4@airtelmail.in, secgenici@airtelmail.in
Website : www.indianconcreteinstitute.org

GSTIN NO:33AAATI0256J1ZX

Please enclose two passport size photos

for Office use only

Member No. ____

Type of Member ____

Centre ____

Date ____

(Fill in BLOCK LETTERS)

1. **Name in full** .....

2 a **Date of Birth:** ☐☐ ☐☐ ☐☐☐☐ b **Age :** ..... 3. **Sex:** M ☐ F ☐ 4. **Qualification:**.....

(Pl. attach document for age proof)

5. **Status:** Student ☐ Employed ☐ Self Employed ☐ Retired ☐

6. **Organisation :** ..... 7. **Designation :** .....

8 **Address :**

	Office	**Residence**
	.....	.....
	.....	.....
	.....	.....
City / Town	.....Pin.....	.....Pin.....
District :	.....	.....
State :	.....	.....
Tel / Mobile:	.....	.....
E-mail :	.....	.....

Communicate to: Office ☐ Residence ☐

9. **Fee Structure:**

	Membership Category	Entrance + Life Membership Fees (One time Payment) Rs.	Total Rs.	GST @ 18%	Grand Total (Payable) Rs.
a	Individual	1,000 + 8,000 (below 60 years) 1,000 + 4,000 (above 60 years)	9,000.00 5,000.00	1,620.00 900.00	10,620.00 5,900.00
b	Overseas Membership	25 US $ + 275 US $	300 US $		

The membership fee is to be added to the Corpus Fund.

10. **Payment Details:** Cash ☐ Cheque ☐ D.D. ☐ Amount ☐ D.D./ Cheque No.....

date ..... drawn on .....(Cheque / D.D. to be drawn in favour of **"Indian Concrete Institute"** payable at Chennai. (OR) Credit to the account of ICI, A/C No.000101208599 in ICICI Bank, Chennai Branch. NEFT / IFSC Code : ICIC0000001).

11. Endorsement of ICI Members

a. Name ..... M. No. .....

Signature .....

Address .....

b. Name ..... M. No.....

Signature .....

Address .....

12. Applicant's Interest in Concrete (Indicate Order of preference a to o)

a Concrete Construction ☐	f. Structural Designs ☐	k. Research & Dev. ☐
b. Reinforcement ☐	g. Special Services ☐	l. Concrete Repairs ☐
c. Precast Concrete ☐	h. Formwork & Moulds ☐	m. Concrete Composites ☐
d. Prestressed Concrete ☐	i. Concrete Equipment ☐	n. Trg.in Concrete Tech. ☐
e. Structural Interest ☐	j. Concrete Testing ☐	o. Others (Please Specify) ☐

13. Nature of Experience .....

.....

.....

14. Area of Specialization .....

.....

15. Contributions to concrete Tech. & construction .....

.....

.....

Date : .....

.....
Signature

Remarks (For Office use Only)

Secretary General

Application for Corporate / Organisational Membership

for Office use only

Member No. ____

Type of Member ____

Centre ____

Date ____

Indian Concrete Institute

No.201, First Floor, Ten Square, No.64, Jawaharlal Nehru Road,
Koyambedu, Chennai - 600 107, Phone : 044 - 24792602, 24795148
Email : ici4@airtelmail.in, secgenici@airtelmail.in
Website : www.indianconcreteinstitute.org

(Fill in BLOCK LETTERS)

1. **Name of the Organisation** .....

.....

2 **Address :** a) **Office**

.....

.....

.....

City / Town .....Pin.....

District : .....

State : .....

Tel / Mobile: .....

E-mail : .....

b) **Representatives**

a. Name : .....

Designation : .....

Mobile No. : .....

E-mail ID : .....

b. Name : .....

Designation : .....

Mobile No. : .....

E-mail ID : .....

Communicate to: Office ☐ Representative ☐

3. **Corporate Membership** Lumpsum Amount : **₹ 5,00,000/-**

4. **Organisational Membership**

A. **Domestic:**

a1. Commercial Organisation Annual (Entrance Fee ₹5,000/- + Membership Fee ₹10,000/-) : **₹ 15,000/-**

a2. Commercial Organisation Life (Entrance Fee ₹5,000/- + Membership Fee ₹95,000/-) : **₹ 1,00,000/-**

a3. Educational Institution / Research Laboratories (Entrance Fee ₹5,000/- + Membership Fee ₹40,000/-) : **₹ 45,000/-**

B. **Overseas:**

Lifetime Subscription Lumpsum Amount : **US $ 3,000/-**

Please add GST @ 18%

The membership fee is to be added to the Corpus Fund.

5. **Payment Details:** Cash ☐ Cheque ☐ D.D. ☐ Amount ____ D.D./ Cheque No.....

date ..... drawn on .....(Cheque / D.D. to be drawn in favour of **"Indian Concrete Institute"** payable at Chennai. (OR) Credit to the account of ICI, A/C No.000101208599 in ICICI Bank, Chennai Branch. NEFT / IFSC Code : ICIC0000001).

PTO

6. Endorsement of ICI Members

a. Name ..... M. No. .....

Signature .....

Address .....

b. Name ..... M. No.....

Signature .....

Address .....

7. Organisation's Interest in Concrete (Indicate Order of preference a to l)

a Manufacturing	☐	g. Consultancy	☐
b. Construction	☐	h. Special Services	☐
c. Education	☐	i. Infrastructure	☐
d. Research	☐	j. Construction Chemicals	☐
e. Goverment Departments	☐	k. Laboratories	☐
f. Construction Machines	☐	l. Others (Please Specify)	☐

8. Nature of Business .....

.....

.....

9. Area of Specialization.....

.....

10. Contributions to concrete Tech. & construction .....

.....

.....

Date : .....

.....
Signature

Remarks (For Office use Only)

Secretary General

Application for Opening of ICI Students Chapter

Indian Concrete Institute

No.201, First Floor, Ten Square Mall, No.64, Jawaharlal Nehru Road,
Koyambedu, Chennai - 600 107, Phone : 044 - 24792602, 24795148
Email : ici4@airtelmail.in, secgenici@airtelmail.in
Website : www.indianconcreteinstitute.org

1. **Name of the College / University** : .....

: .....

2. **ICI Organizational Membership No** : ..... 3. **Date of Joining** ☐☐ ☐☐ ☐☐☐☐

4. **Membership Details of Four Faculty Members (Name and Membership No.)** :

a. ..... b. .....

c. ..... d. .....

5. **Institute Address:**

.....

.....

.....

.....

City / Town : .....Pin .....

District : ..... State :.....

Telephone : .....

E-mail : .....

Particulars of H.O.D. & Students Chapter Coordinator

a. Name : .....

Designation : .....

Mobile No. : .....

E-mail ID : .....

b. Name : .....

Designation : .....

Mobile No. : .....

E-mail ID : .....

6. **No. of Student Members :** ☐☐☐☐

7. **Fee Structure:**

Sl.No.	Year of Study	Applicable fees (includes GST 18%) Rs.	Period	No. of Members	Grand Total Rs.
1.	First Year	1400	For all Four Years.		
2.	Second Year	1200	For Three Years.		
3.	Third Year	900	For Two Years.		
4.	Fourth Year	500	For One Year		
5.	PG	500	Per Year.		

8 . **Payment Details:** Cash ☐ Cheque ☐ D.D. ☐ Amount ☐ D.D./ Cheque No.....

date ..... drawn on .....(Cheque / D.D. to be drawn in favour of **"Indian Concrete Institute"** payable at Chennai. (OR) Credit to the account of ICI, A/C No.000101208599 in ICICI Bank, Chennai Branch. NEFT / IFSC Code : ICIC0000001).

Note: (i) Please fill up the LIST OF STUDENT MEMBERS format shown in the second page.

(ii) If a student member wants to become a regular member either the fee paid by him/her or the entrance fee, whichever is lower will be adjusted against the total fee payable.

Date: .....

Seal & Signature of Principal / H.O.D.

PTO

STUDENT CHAPTERS

1. FORMATION OF STUDENTS CHAPTER

Any educational institution having more than 60 students in Civil and allied engineering branches can request the Chairman of the nearby center of the ICI or the Vice-President of the region/President/Secretary General at the headquarters the intention of the education institute to open a student's chapter. The Institute should satisfy the following conditions:

1. The Institute shall become an organizational life member of ICI and atleast four faculty members shall be members of ICI.
2. Atleast 50% of the students subject to a minimum of 60 shall become student members.
3. i. The Institute shall undertake to organize atleast two technical lectures by eminent personality from the construction industry in each semester.
   ii. Organise technical report writing competition among students atleast once in a year.
   iii. Undertake technical visit to construction site and write report on their visits atleast once in a year.
   iv. Any other technical activity like exposition of new building material, etc., as option.

STUDENT MEMBERSHIP BENEFITS

Benefits of ICI Students Chapter

- Concessional Delegate fee for participation in ICI events, to get updated on the latest technology & practices in Concrete Industry.
- ICI Events provide unique opportunity to listen to, and to interact with experts from within the country and abroad.
- Concessional rates for Publications of ICI.
- Support to conduct Training Programmes, Workshops, Conferences, Site Visits etc.
- Support in calling professionals in civil engineering for delivering Guest Lectures, on topics of interest.
- “ICI-Update” a monthly e-bulletin from ICI, to keep abreast of the happenings in ICI and to know the Forthcoming Events.
- Opportunity to participate in ICI conducted competitions like ICI FEST, which is a zonal meet of Students Chapters.
- Waiver of entrance fee to become Life Member of ICI, after graduation.
- Access to ICI Archives, which is a collection of valuable Technical Papers.
- Access to ICI reference library.

INCI - RETROFIT

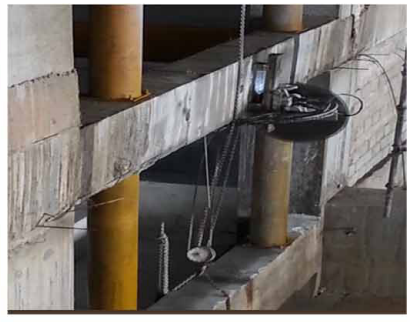
Repairs, Retrofitting, Soil Stabilization






- Concrete Repairs
- Guniting / Shotcreting
- Soil stabilization by Micro piling, Driven and Grouted Nails
- Anchoring
- Concrete cutting & sawing
- Drilling & grouting
- Carbon laminate & fibre applications






Room No: 1, 1400, 2nd floor, 41st main, Kanakapura Road, Sarakki Gate, JP Nagar, 1st phase, Bangalore.
Ph: 080- 2244 7700, +91-9741110366, Email : **kannanretro@gmail.com, kannan@inciretrofit.com**
Web : www.inciretrofit.com

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