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Ambuja Technical Journal

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ENGINEER · ARCHITECT · STRUCTURAL ENGINEER · CEMENT · SKILL

Come... Partner with us
as we build the Foundations of the future

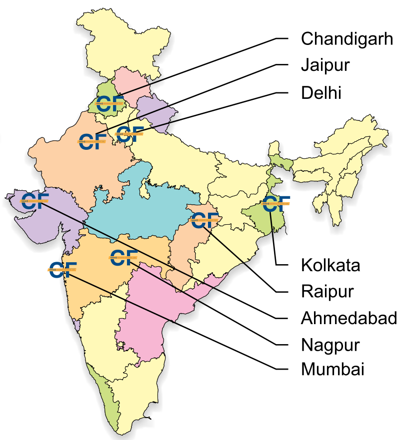
We have raised the bar of our labs, they are now NABL accredited

Ambuja Cements, Concrete Futures Laboratory (CFL) have earned National Accreditation Board for Testing and Calibration Laboratories (NABL) accreditation.
And, as such they are designed for almost 0% error to carry out the following testing :

- Concrete Material - coarse and fine aggregates
- Physical properties of concrete

Besides, we also offer concrete mix design services for :

- Concrete up to M55 Grades
- High Strength & High Performance Concrete above M55 Grade
- Self Compacting Concrete
- Fiber Reinforced Concrete
- High Volume Fly Ash Concrete
- Pavement Quality Concrete
- Pervious Concrete
- Light Weight Concrete & High Density Concrete



Our CFL Labs are equipped to provide some very special tests like HolcimCone™ (to assess mechanical & rheological properties of concrete by testing its mortar), HolcimBlu™ (to quantify clay contamination in sand) and HolcimShape™ (to study shape and texture of fine aggregates).

Currently, we have 8 such laboratories and planning for more for providing services to make stronger and better structures.

Ambuja Cement
Giant Compressive Strength

Ambuja | CONCRETE FUTURES LAB

EDITORIAL

This 5th edition we bring to you one of the marvels in Construction, with the use of world's best technology & creating a FIRST of its kind, BIDIRECTIONAL Tunnel in India.

The 9.2 km long Chenani-Nashri Tunnel, constructed in the lower Himalayan ranges under the most challenging climatic condition like heavy snowfall in winter and difficult geology & terrain of the young Himalayan Mountains, is a class apart, which reduces the distance between Jammu to Srinagar by 30Kms.

The tunnel is located at an elevation of 1200 m and was built using the latest NATM technique of sequential excavation and support. A detailed article on the Chenani-Nashri tunnel has been included in this edition & we are sure it would be a source of inspiration & revelation to the construction engineers & experts alike.

This is followed by many interesting articles like Mineralogical characteristics of fly ash for durable blended cement concrete elaborating interrelations of the fly ash & OPC characteristics, Basic guidelines on use of TMT reinforcement bars In RCC construction & highrise buildings, Assessment of carbonation depth under natural and accelerated carbonation conditions, BIM - new approach of "Virtual Building Construction" based on parametric CAD technology, Fiber reinforced concrete etc…

As promised, we strive once again to give you the best in the cement & construction segment.

HAPPY READING !!!

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Chenani-Nashri Tunnel

J S Rathore

Introduction

The Chenani-Nashri Tunnel is the India's longest road tunnel completed in Udhampur district of Jammu and Kashmir. **The 9.2 km long road tunnel is a major road tunnel project in Northern India and biggest of the country which includes (9Km Main tunnel + 9Km Escape Tunnel + 1Km Cross Passage = total tunnelling done is 19 Km.** Highest progress achieved in a Month from 4-Faces was 850 m which is record in Himalayan Tunnel by NATM.

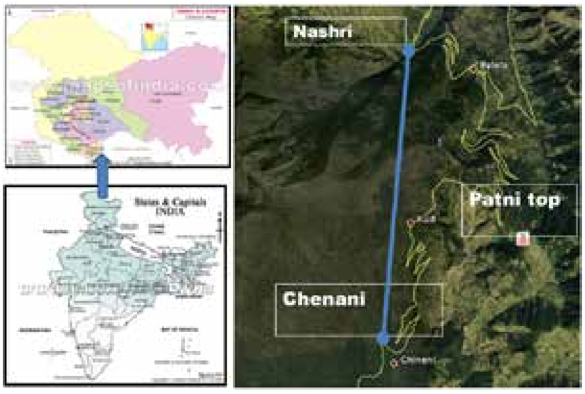

Figure 1. Location Map

IL&FS Transportation Network Limited has produced Master piece, state of art tunnel and this tunnel, is a stunning example of engineering marvel. The Shivalik mountain range of the great Himalayas now hosts the India's longest 2 way traffic road tunnel. This 9.2 Km tunnel is different from many other tunnels in India as well as other parts of the world as it is two lane tunnel with parallel escape tunnel connected with 29 Nos. cross passages.

It will reduce 30 Km distance from Jammu to Srinagar and reduce traffic jams on NH-1A that occur due to snowfall and avalanche in winter at Patnitop. In addition to the main road tunnel, there is a smaller parallel escape tunnel for emergency services for persons and extraction of smoke from fully Transversal ventilation system in case of fire and accident.

It is one of world best latest technology used tunnel and First in India Bidirectional tunnel with fully transversal ventilation system controlled by integration tunnel control system with all those features required for safety of road user. It is also completely water proof tunnel.

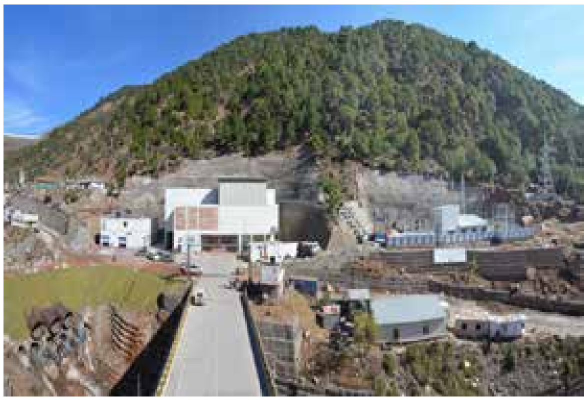

Figure 2. Outer Tunnel View

Figure 3. During Construction

Uniqueness of the project/ innovation done in Project

To achieve good progress under safe working condition some innovation has been done Chenani-Nashri Tunnel Project.

- Use of poly fibre/steel fibre shotcrete replacing traditional Wire mesh system
- Using Swellex rock bolt immediately with layer of sacrificial shortcret
- Deformation monitoring by reflex targets, pressure/load cell and in extreme condition MPBX results to optimize the support.
- Probing (drilling up to 12 m advance at face) of tunnel where ever suspicion of shear /fault zone and water ingress etc.
- Use of automatic navigated boomer (first time in India) for drilling which has resulted reduction drilling time and accuracy.
- Mucking time is reduced by using 35 ton capacity articulated trailer called GHH-Germany made.
- Specialized team of Experts called in tunneling field time to time for advice and suggestion.

- Unique electro-mechanical design and implementation procedures
- Fully Integrated Tunnel Control System for integration of Power supply, Traffic, Communication, Fire fighting & Ventilation.
- First in South East Asia and amongst very few tunnels across world with transverse ventilation. Working in young immature Himalayan rocks and geological uncertainty in Himalayan terrain is a huge challenge. Overcame same using probabilistic approach and NATM rather than TBM.

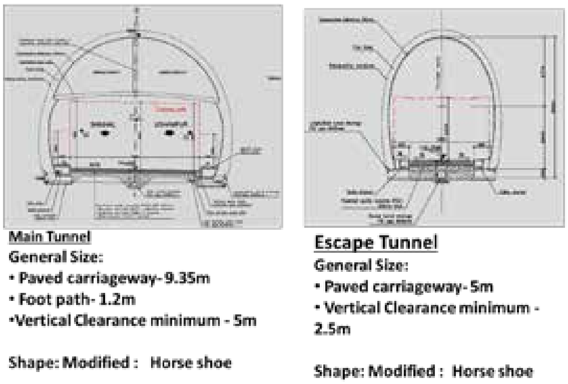

Figure 4. Tunnel Cross Section

Challenges faces during Project implementation:

- The behaviour of flysch (mixed rock faces) formations is not easily determined. Needed, careful and experienced blasting.
- Mixed Lithology & Challenges. Needed to optimize blast, else overbreak and muck would increase.
- Adopted multiple methods to overcome the geological challenges of Himalayan region.
- Geological problems like sudden ingress of water in North portal towards Nashri.
- Interception of shear/fault zones in South portal because of negotiating low vertical and lateral cover zones.
- At middle of tunnel where rock cover was 1050 m, high stress conditions appeared inside the tunnel resulting in rock bursting and squeezing.
- Road connectivity due to landslides, snowfall and traffic jam was also major huddle many days in raining and winter season during execution of Project.
- Social and political reason also disrupted the Project work in tendon many days.
- Labour unrest was the most affecting factor which has disruption in execution of Project more 150 days

Figure 5. Phases of Construction

Geology

Rock mass: Sedimentary deposits of mudstone and sandstone of the Murree Formation (Flysch) with a typical alternation of sandstones and siltstone or claystone beds.

Lithologies:

- **SANDSTONE** - grey to purple, fine to coarse grained, high strength, massive to joint. Closely to highly jointed with infill. of medium strength. Thickness varies from 2 to 12 m.

- **SILTSTONE** - fine grained with well-developed bedding laminations. Thickness varies from few centimetres to metres; often inter-bedded with the claystone.

- **CLAYSTONE** - dark purple, fine grained, soft to fairly hard, highly jointed with susceptibility to weathering, friable when dry. Typically thinly bedded.

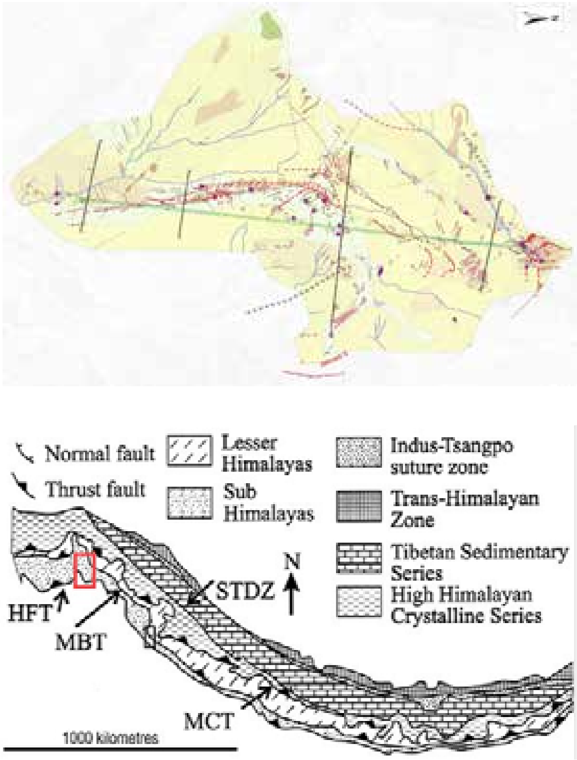

Figure 6. Rock Zones

UCS of Rocks:

- Sandstone: 70-120MPa
- Siltstone: 25-40MPa
- Claystone: 8-15MPa

Concrete Grades used in the Project :

In the project, various grades of concrete starting from M15 to M40 were used. Different grades were used for different applications as shown below:

- M15 for PCC
- M25 for Shotcrete
- M30 for Lining
- M35 for retaining walls
- M45 for Bridges.

Impediments:

Chenani-Nashri Tunnel is found to be a challenging during excavation of tunnel due to uncertain, difficult, extremely variable and complex geological conditions emerging out of young Himalayan mountain building processes.

Moreover, extremely rugged, densely forested, and inaccessible topography limit the scope for investigation which finally becomes a cause of concern during execution due to geological problems like sudden ingress of water in North portal towards Nashri and ,interception of shear/ fault zones in South portal because negotiating low vertical and lateral cover zones and at Middle high stress conditions inside tunnel resulting in rock bursting and squeezing, high temperature condition inside tunnels .

Road connectivity due to landslides, snowfall and traffic jam was also major huddle many days in raining and winter season during execution of Project.

Social and political reason also disrupted the Project work in tendon many days

Labour unrest was the most affecting factor which has disruption in execution of Project more 150 days

Figure 7. View of Gantries

Special Safety Features

Chenani Nashri Tunnel Which is an underground transport infrastructure requires very high level of safety standards to be adopted to ensure safe and efficient passage to commuters.

International safety standards have been adopted for this tunnel:

1. Redundancy in the system
2. Entrance vehicle detection
3. Automated smoke & Fire Alarm
4. Authomatic Incident Detection
5. Integrated Traffic Control

6. Automated control of traffic per incidence
7. Automatic VMS (Variable Messaes Sign)
8. Public Address System (Global & Local)
9. Re-broadcasting & breaking of FM
10. Dedicated VHF network
11. Fire Fighting with hydrants and active suppression using latest vehicle mounted system
12. Integrated system control of Ventilation. Traffic, tolling, etc.
13. Special assistance to differently abled person

Dedication of the Tunnel to the Nation: Chenani-Nashri Tunnel was dedicated to nation on 2nd April, 2017 by Honourable Prime Minister of India Sh. Narendra Modi.

TUNNELLING ASSOCIATION OF INDIA
[Affiliated to International Tunneling and Underground Space Association (ITA)]

TAI Tunneling and Underground Space awarded Chenani Nashri Tunnel Project as Best Tunneling Project of the year on-9th Feb 2017

Overall Appreciation of the project:-

- IL&FS Transportation Network Ltd. has shown outstanding capabilities in being able to manage a project despite large and unexpected technical, contractual & financial issues.
- Expertise gained can be utilised become self-sufficient in building tunnels.
- Despite many odds, difficult conditions, project team has shown resistance to overcome those problems and had stand in front the challenges and deliver best of their capabilities.
- This Tunnel, even with small delays would be the fastest to complete in India, in the Himalayan region.

J S Rathore

Project Director (Chenani-Nashri Tunnel Project in J &K)
He is currently working for IL&FS Transportation Network limited in India as Project Director - Chenani Nashri HighwayTunnel Project in J&K.

Engineering the Chemico-Mineralogical Characteristics of Fly Ash for Durable Blended Cement Concrete

S.A.Khadilkar,
R.M.Cursetji, M.V.Karandikar

Summary

The country in last decade has gradually seen a growing acceptance for the fly ash blended cements. The improved understanding of the beneficial properties imparted by fly ash for both the plastic and hardened stages of blended cement concrete has led to the use of fly ash based cements for some of the major projects in the country. The enhanced durability of blended cement concretes has made it the preferred cement thereby replacing the earlier skepticism regarding its performance.

It is now beyond doubts that in the Tropical climatic condition of the country, Blended cement concrete either with the blending component as a part in cement or alternatively as site blended at the Ready – Mix locations, is the option for a durable civil structure. The choice being governed by the judiciousness of quality control of the properties of the individual components at the manufacturing stage of the blended cement or at the Ready-Mix locations.

The fly ash characteristics such as the combustible content, particle shape & size distribution of the fly ash and its Chemico-mineralogical characteristics i.e its oxide composition, nature & contents of the crystallites and the amorphous glassy phase have been observed to substantially influence the properties of the blended cement and concrete. These properties being dependent on coal characteristics and on the operating conditions of the coal fired thermal plants as also on the collection points of the fly ashes.

The paper discusses in some details, the effect of the compositional characteristics of the amorphous glassy phase & the nature of crystalline contents of the fly ash on its enhanced pozzolanic reactivity, the early and later age strength developments of the blended cement and the influence on the properties related to durability of the concrete such as resistance to reinforcement corrosion, resistance to sulphate attack and resistance to expansion due to ASR reaction.

A proper understanding of these interrelations of the fly ash & OPC characteristics is of immense importance for engineering the properties of the blended cements for durable Concrete.

Introduction

In the Tropical climatic condition of the country, fly ash based Blended concrete is being presently equivocally accepted as an option for durable concrete structure. The blended concrete being produced either with use of blended cements or through site blending of fly ash in Ready Mix plants. The performance characteristics of the blended concrete would be function of the characteristics of the fly ash used as well as homogenous blending of this lighter and finer component in the blended cement / blended concrete.

At the Research & Consultancy Directorate of The Associated Cement Cos. Ltd., considerable studies have been carried out on the fly ashes of different coal fired thermal plants and of differing compositions and mineralogy to understand the influence of fly ash characteristics on the properties of resultant cements and concrete. The studies indicate that the fly ash characteristics play a significant role in determining the performance of the cements and concrete. An understanding on this interrelationship thus would help in engineering the fly ash properties of the available fly ash so as to produce blended cement / concrete with improved performance.

It is of proven understanding that the characteristics of fly ash produced in the coal fired thermal plant is a function of nature of the coal, coal comminution system, boiler type & efficiency, fly ash collection ESP fields, loading at which the thermal plant operates etc., as a result from the same source the fly ash characteristics could vary substantially.

In India the chemico - mineralogical characteristics of dry fly ash produced, has been observed to vary considerably. The mineralogy of fly ash available in the country shows 15 - 30% Mullite, 15 - 45 % Quartz, 1 - 5% Magnetite, 1 - 5% Hematite and around 25 - 35% of amorphous glassy alumino - silicate phase (1), the fineness of the fly ash from the different thermal plants in the country ranges from 12 % to 50 % residue on 45 microns. The scenario thus necessitates that the available fly ash to be engineered so as to produce consistent Blended Cement.

The paper discusses the effect of the chemico - mineralogical characteristics of the fly ash on its enhanced pozzolanic reactivity, the early and later age strength developments of the blended cement and its influence on the concrete properties related to durability of the concrete such as resistance to reinforcement corrosion, resistance to sulphate attack and resistance to expansion due to ASR reaction.

Use of Fly ash imparts a number of technical benefits to concrete both in the plastic and hardened states. These benefits are derived from both the physical and chemical properties of fly ash such as combustible content, mineralogy the extent of crystallites and amorphous glassy phase and in particular, the finer fraction of fly ash, i.e. those particles that are less than 45%. These particles act as a solid particulate plasticiser. The sphericity of the particles and fine size of the fly ash, act like ball bearings and as plasticiser, within the concrete, reducing the water requirement for a given workability. A reduction in the water content lowers the permeability and increases strength and durability. In addition the concrete is more cohesive, has a lower rate of bleeding and is less prone to segregation.

Based on the experimentally observed results with Fly ash based Composite Cement & the reported data on the effect of use low lime Class-F fly ash based cement / concrete on the properties of the concrete, the authors make an attempt at evolving an understanding of the influence of the properties and reaction mechanics of the fly ash component in determining the limiting / favoring conditions for improved properties related to the durability of the concrete.

Fly ash Characteristics - Influences on Properties of Cement & concrete

Combustibles in fly ash:

The carbon or combustible contents of fly ash suitability has been determined by loss-on-ignition (LOI, a measure of carbon mass), it is the carbon's porous surface area which is more important, because this determines the capacity of the carbon to adsorb air entrainment admixtures or other chemical admixtures (2,3).

This adsorption is undesirable, as it degrades the freeze-thaw resistance of the concrete because air bubble content is lowered. Most fly ash carbon samples have surface areas much larger than would be expected from the external geometric area of the particles. This is because the carbon particles have a large amount of porosity contributed from the micropores (<20Å), mesopores (20Å-500Å) and macropores (>500Å). Three microscopically distinct carbon types have been reported to be present in high carbon fly ashes i)inertinite , which appears to have been entrained in the particles , prior to meting or combustion ii)isotopic and iii) anisotropic carbon which appear to have passed through the melting stage. It has been observed that the capacity of the carbon in fly ash to adsorb the chemical admixtures is a function of the type of carbon present in the fly ash (4) and thus it is not always related to the LOI or carbon content of the fly ash.

The porosity in carbons contained in class C ashes differs from that in class F Fly ash (5) in two important characteristics. First, the carbons in class C ashes generally contain significantly more micro-porosity, as revealed by standard nitrogen isotherm data, and the BET surface areas derived therefrom. It is typical for class C carbons to have a surface area in the range of 300 to 400 m2/g, whereas the carbons from class F ashes have surface areas which are typically in the range from about 30 to 70 m2/g. Some unusually bad class F ashes have carbon surface areas, which approach those in class C ashes. A second difference in the porosities observed in the carbons from class C and class F ashes has to do with the total amount of porosity per mass of carbon. The carbons from class F ashes tend to be somewhat less porous than the carbons from class C ashes.

Presence of high carbon in fly ash thus could result in increased requirement of chemical admixtures, the high-carbon fly ash tend to use more water (5) thus affect the compressive strength characteristics of the resultant blended cements of fly ash based blended concrete. The presence of carbon content would also darken the cement and concrete as well. It is not recommended to use a high-carbon (> 5 percent) content fly ash, but if used, the dosages of air-entraining agent and other chemical admixtures need to be optimised with the use high carbon fly ash . The Fig.1 depicts the effect of carbon content in fly ash on physical properties of the resultant PPC (Portland Pozzolana Cement) (Indian standards).

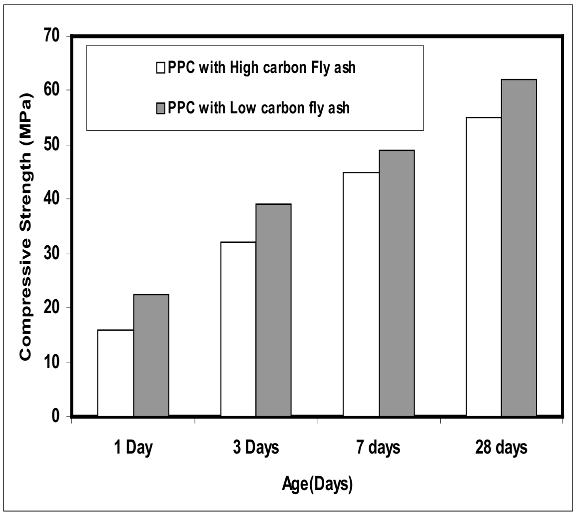

Figure1 : Effect of high carbon content in fly ash on compressive strength

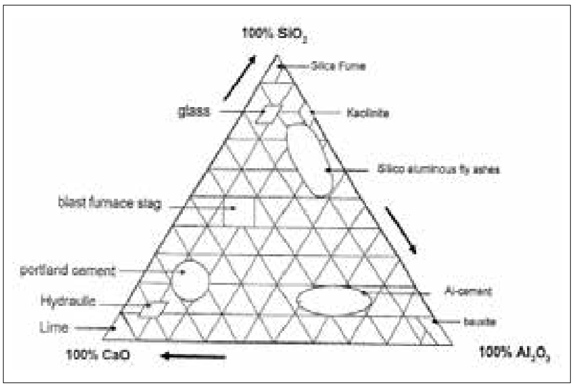

Figure 2: SiO2-Al2O3-CaO system showing relative positions of cements and cementitious materials CSH gels & slags

Chemico - Mineralogical properties of fly ash:

In India the chemico - mineralogical characteristics of dry fly ash produced, has been observed to vary. The mineralogy of fly ash has 15 -30% Mullite, 15-45 % Quartz, 1-5% Magnetite, 1-5% Hematite and around 25 - 35% of amorphous glassy alumino - silicate phase.

The ternary phase diagram of SiO2-Al2O3-CaO indicates the relative positions of cementitious materials. As the lime in the fly ashes increases i.e. as the fly ash composition changes from low lime Class-F fly ash to lime containing Class - C fly ashes their relative position moves towards the centre of the ternary diagram. In the high lime Class - C fly ashes besides the presence of crystalline hydraulic Calcium aluminates (C3A), the amorphous glassy phase is calcium rich and more reactive than the alumino silicatic amorphous phase of Low Lime Class - F fly ashes, which is comparatively latently hydraulic (6,7,8).

The amorphous phase in fly ash is thus the reactive part in fly ash responsible for the secondary hydration and the consumption of free calcium hydroxide during the pozzolanic reactions. The crystalline phases of fly ashes such as Mullite, quartz, hematite, magnetite are non hydraulic while crystalline calcium aluminate phases present in some of the Class - C fly ashes are cementitious in nature. Thus the chemico-mineralogical composition of the fly ash determines the reactivity of the fly ashes, it also has a bearing on the concrete properties determining the durability of the concrete structures such as Sulphate resistance, corrosion resistance, resistance to the ASR expansion etc.

Effect of Mineralogical composition of the fly ash:

It would be immensely important to understand that the characteristics of fly ashes are assemblages of particles produced by combustion and melting of individual small particles of ground coal. Each particle is heated and undergoes changes independently of other particles, while passing through the burning zone of the power plant boiler. Its composition reflects that of the inorganic portion of the particular coal fragment, with whatever changes have occurred due to selective vaporization of components and perhaps subsequent surface deposition. In any of these events, the composition of each particle is necessarily different from its neighboring particles and overall chemical analysis is only an average description of the assemblage. Another feature of fly ash is that individual fly ash particle vary in content of crystalline component like quartz, Mullite, Iron oxide, calcium bearing compounds (in Class C fly ashes) and amorphous or glassy phases.

As discussed above a considerable distinction exists between low lime class F fly ash from bituminous coal and high lime class C fly ash produced from lignitic or sub-bituminous coal. Depending on composition of the clay mineral constituents, the boiler temperatures, coal fineness used in the boiler type as well as the efficiency of the heat recuperation systems the fly ashes would show a difference in the glassy amorphous phase contents and the nature and extent of minerals present. Which would determine the pozzolanic potential of the fly ash and its resultant effect on the performance characteristics of the cements / concrete.

The fig 3 depicts comparative pozzolanic reactivity of two compositionally similar low lime class - F fly ashes differing in Mineralogy and amorphous contents. The method used has been evolved at the authors laboratory for comparing the reactivity of fly ashes (9) The XRD showing the difference in mineralogy is shown in Figure 4.

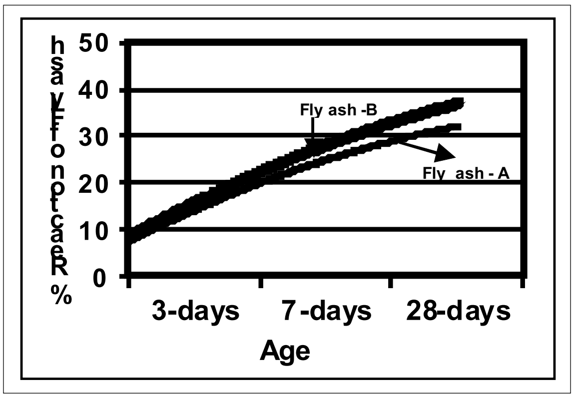

Figure 3: Comparative Pozzolanic reactivity of Class F Fly ashes differeing in the amorphous content

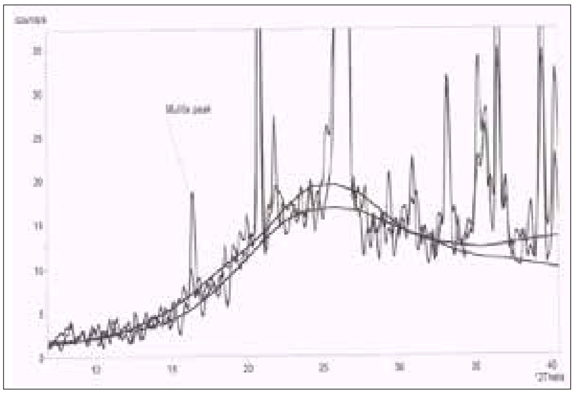

Figure 4: XRD fly ashes of differing mineralogy

Effect of amorphous phase composition of the fly ash :

It has been observed that as the composition of the amorphous phase changes that is as the alumino-silicate amorphous glassy phase becomes calcium rich or as the Si /Al ratio of the amorphous phase changes there is distinct shift observed in the peak maxima of the amorphous hump observed in XRD, i.e there is a shift in the maxima of the amorphous hump towards that of the hump maxima of the granulated blast furnace slag. This could be related to the changes in the composition of the amorphous glassy phase, however some more evaluations need to be done to confirm and quantify this observation.

The fig 5 depicts the amorphous hump maxima of different fly ashes of different CaO content, the figure also shows the nature of the amorphous hump of silica fume, metakaolin and GGBS for comparison.

As already indicated that the lime rich amorphous alumino silicate has higher pozzolanic reactivity. Fig 6 depicts the compressive strength characteristics of PPC made with different amorphous phase compsotion.

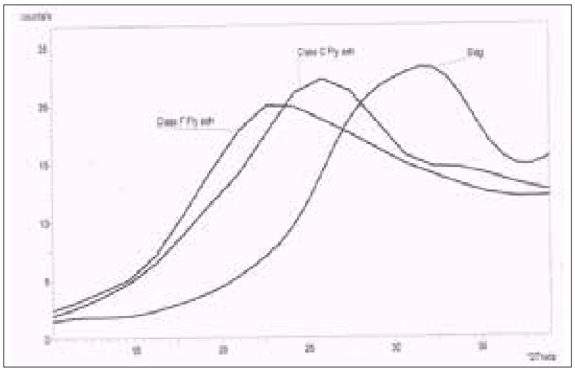

Figure 5: XRD of fly ashes with different S/A showing difference in amorphous humps

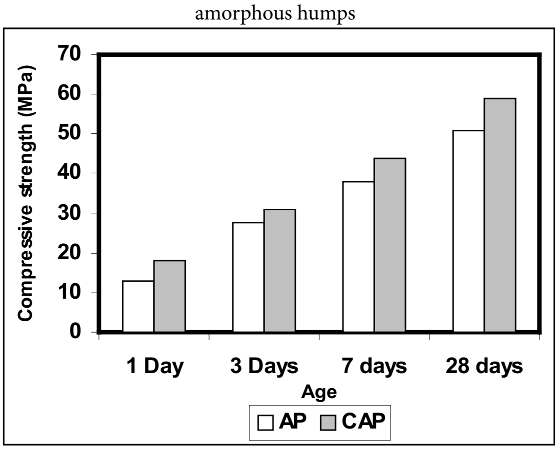

Figure 6: Compressive Strength of PPC with Fly ash AP & CAP

Particle size Distribution of fly ash :

Fly ash as a finer product contributes the performance of the resultant cement and concrete as a pozzolanic additive, as an inert/reactive filler and as an inorganic particulate plasticiser because the sphericity of and smaller size of its particles.

As discussed earlier the fineness of the fly ash available from a given source varies considerably depending on the ESP field from which it is collected as well as other operational parameters of the thermal plant. On an average the fineness in terms of residues on 45 microns ranges from 12 to 50 %.

The fig 7 illustrates (11) the mortar properties with 30 % fly ash of different size fractions, it indicates that the each size fraction of the fly ash tends to behave differently and have different influence on the pozzolanic properties

Studies carried out at the authors laboratory (12) have helped evolve an understanding of the influence of the particle characteristics and reaction mechanics of the fly ash component and it could be stated with a high degree of confidence that by optimization of the comminution system, an engineered particle size distribution of fly ash can be achieved in the size fractions of the resultant cement(Fig.7) which enhances the pozzolanic activity fly ash and helps improve the performance of the resultant blended cement. Fig.8 &9 illustrates mortar and concrete properties of the Normal PPC and Engineered PPC.

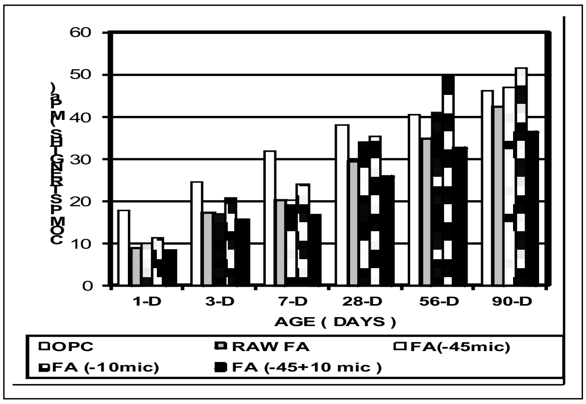

Figure 7: Compressive Strengths at different ages with 30 % Fly Ash of different fineness

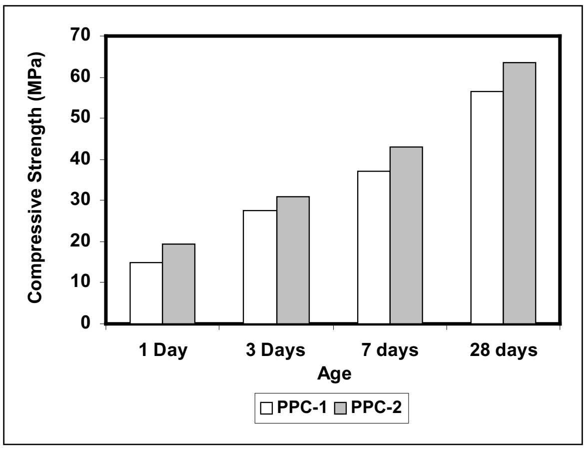

Figure 8: Mortar Properties of Normal PPC and Engineered PPC with 25% fly ash

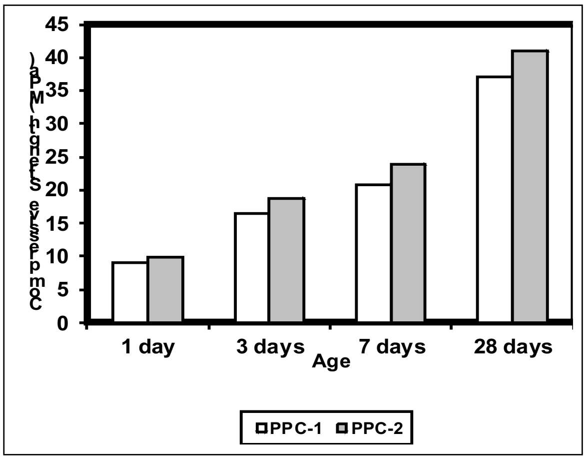

Figure 9 Concrete Properties of Normal PPC and with Engineered PPC with 25% fly ash

Influence of fly ash Characteristics on properties of Concrete

The fly ash characteristics discussed earlier results in changes in the properties of the fresh as well as hardened fly ash based blended concrete .

- Improved workability and pumpability, Reduced bleeding and segregation
- Lower drying shrinkage due to the lower water demand of the fly ash.
- Improved surface finish: Due to increased fineness and higher cohesiveness of the fly ash based Cements
- Lower heat of hydration due to the slower initial rate of reaction of the fly ash, which reduces the peak temperature and the risk of thermally induced cracking.
- Similar setting time as OPC: The fly ash blended cements with engineered particle size distribution have similar setting time to OPC, at times the clinker phase composition needs to be marginally modified.
- Increased long - term strengths due to the continuing pozzolanic reaction between the fly ash and the lime produced during the hydration of the Portland cement.
- Reduced porosity and permeability due to the pore-filling characteristics of the fine fly ash particles and their reaction products. This also leads to denser concrete, which reduces shrinkage, creep and gives greater resistance to chloride ingress and sulfate attack.
- Increased resistance to sulfate attack and chloride penetration

- Increased resistance to alkali aggregate reaction with fly ash at or above 20% of the total cementitious content.

Effect on workability , water requirement with use of Fly ash based cements

The small size, relative sphericity of the fly ash particles in these cements influence the rheological properties of the cement pastes causing a reduction in the water required or an increase in workability compared with that of an equivalent paste of OPC. This improved workability thus allows a reduction in the amount of water used in the concrete with use of the Pozzolanic Cement (Fly ash based cements) (Fig.10). As compared to the OPC concrete the reduction of water requirement is 7.5–9.4 %. Thus at the lower water content the Pozzolanic cement / concrete would show higher compressive strength.

The Pozzolanic Cement generally shows reduced segregation and bleeding and is more satisfactory than OPC concrete in its pumpability characteristics. At site this aspect needs to be understood and its difference from the general OPC needs to kept in mind to derive the benefit from this behavior of the Pozzolanic Cement.

Leaching :

As compared to OPC, the hydrated pastes of the fly ash based cement show decreased leachability. The main reasons behind the leaching resistance are:

- The hydrated cement paste matrix of the Pozzolanic cements show comparatively lower levels free calcium hydroxide than OPC, at same age of hydration, as a part of the liberated free calcium hydroxide liberated from the hydration of the OPC component, reacts with the reactive silica/ alumino-silicate of the Fly ash thus reducing the available free calcium hydroxide, Fig.11 illustrates the free calcium hydroxide present in hydrated OPC and PPC at different ages of hydration.
- The hydrated products formed from the secondary hydration reactions fill in the pores in the hydrated matrix thus reducing the permeability and interconnected porosity of the PPC concrete which prevents the percolation of water and thereby decreases the transport of the calcium ions in the hydrated concrete mass , there by reducing the extent of leaching.

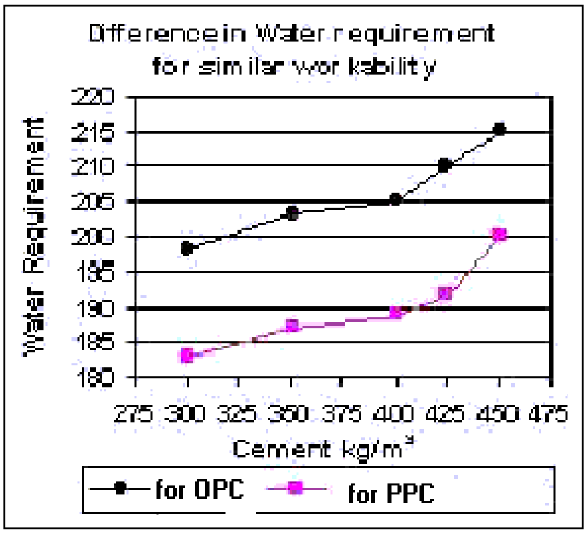

Figure 10: Water requirement of PPC and OPC for equal workability in concrete

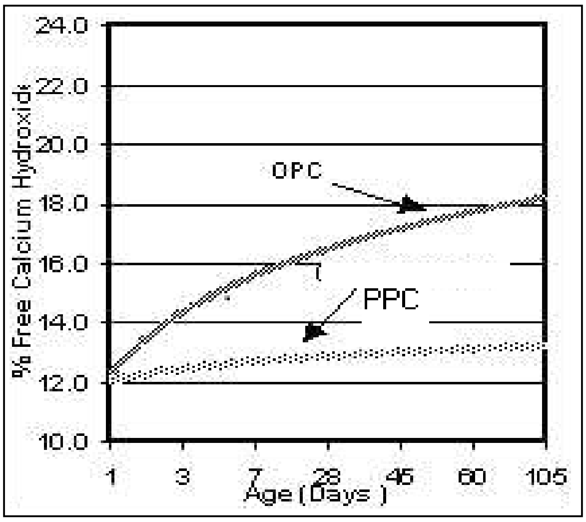

Figure 11: Comparative Free calcium hydroxide content of cement pastes at different ages of hydration

Heat of Hydration:

The Heat of hydration of an high strength OPC typically is in the range of 60 - 75 cal /g at 3 - days and 70 - 85 cal / g at 28 - days the values being dependent on the phase composition of the clinker and the fineness of the OPC. The higher heat of hydration results into increased temperature of the concrete.

Incorporation of fly ash reduces the temperature rise in concrete almost in direct proportion to the amount of Portland cement replaced, partially by delaying heat evolution (due to slower rate of reaction and partially by reducing the total heat evolved. The Fly ash absorption levels in Pozzolanic cement however need to be optimized to balance the compressive strengths and Heat of Hydration thus abating cracking and are thus more suitable for mass concreting. Typically the PPC has a heat of hydration of 50 - 55 cal /g at 3 - days and 65 - 68 cal / g at 28 - days (Fig. 12). This low heat of hydration of these cements can be used to good advantage during hot-weather concreting.

Fig. 13 gives a comparative temperature of the OPC concrete with that of PPC concrete.

The high strength OPC concrete is thus more prone to shrinkage / thermal cracks which would permit moisture and acidic ions like SO2, CO2 penetrate into concrete and react with the high levels of free hydrated lime available causing structural instability thus making the OPC concrete more prone for chemical attacks.

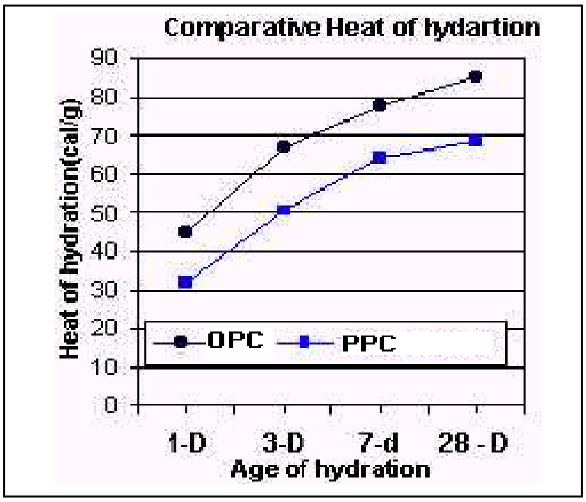

Figure 12: Heat of hydration of OPC and PPC at different ages of hydration

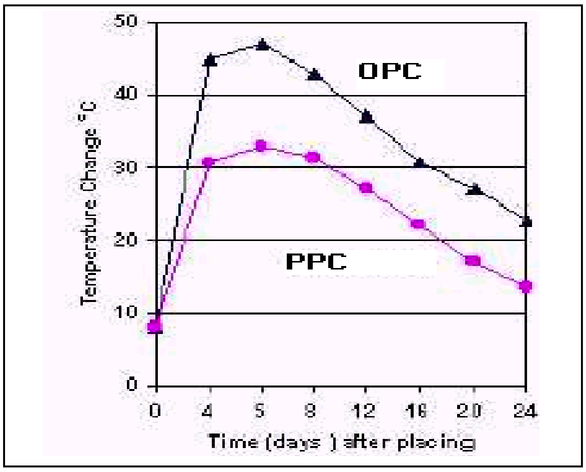

Figure 13: Temperature rise in OPC and PPC concrete

Permeability:

Fly ash based blended cements have higher fineness with the fly ash particles distributed in the finer fractions of the cement, the slow pozzolanic reaction produces a more denser impermeable cement paste matrix. Thus in the fly ash based cement concrete, the Maximum Continuos Diameter and Average Pore diameter is lower than that in OPC concrete. The slower hydration of the pozzolanic component continues in the capillary pores resulting into mass precipitating of the gel products into these pores consequently decreasing the permeability of the concrete.

This decreased permeability of the PPC concrete results in a better flexural/compressive strength ratio and reduced tendency towards cracking. It also accounts for the reduced gas diffusion, lower depths of carbonation and there by maintaining alkalinity of the pore solution and reducing the susceptibility of reinforcement to corrosion. The lowered permeability blended cement concrete also results in decreased tendency of leaching out of lime in these concrete.

The water retention property and lower heat of hydration of the fly ash based Cements help keep the micro climate of the concrete at suitable temperatures of around 30oC and maintain the humidity around 80% in the initial stages of hydration thus facilitating the concrete hardening process .The reduced micro-cracking at the interface in these concrete improves the interface bond as observed in the micro structure.

Comparison of Microstructure of OPC & Blended Cement Concrete

On comparison of both the concretes, the notable feature observed is a dense orientation of Portlandite (calcium hydroxide crystals) at 90% to the aggregate surface. Such type of preferential orientation is almost missing in the M20 composite cement concrete. A dark channel (Fig.14a) is observed at the interphase between aggregate and the bulk hydrated cement paste, this is the weak link in the OPC concrete, however, in the blended cement concrete of the same age, the channel width is much reduced and there is development of C-S-H gel over the aggregate surface. The bulk hydrated cement paste is also relatively denser as compared to OPC concrete and the compaction increases with age of hydration. The comparative microstructure is illustrated in Fig.14a & Fig.14b.

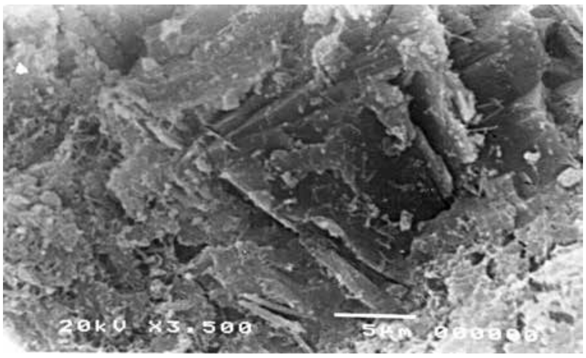

Figure14a: SEM photomicrograph of OPC concrete M20(90-days)

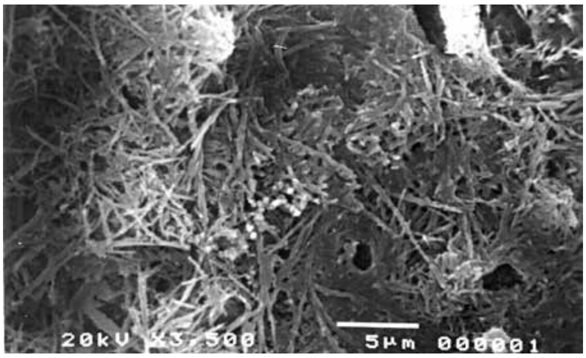

Figure14b: SEM photomicrograph of OPC concrete M20(90-days)

Corrosion Resistance:

The concrete cover over the reinforcement is sufficiently thick and impermeable , it provides adequate resistance to corrosion .The protective effect of concrete is both physical and chemical and functions in three ways

- It provides alkalinity in the vicinity of the steel.
- It provides physical & chemical barrier to ingress of moisture, oxygen carbon dioxide, chlorides and other aggressive chemicals
- Provides electrical resistivity around the steel .

The corrosion process of the reinforced steel can be described in a simplified way (12) by an equivalent electrical circuit and the corrosion current (I corr) can be expressed as Studies carried out(14,15) indicates that onset of corrosion takes place when molar ratio [Cl-] / [OH-] crosses 0.6. In order to have a qualitative information on state of corrosion ASTM C - 876 - 91 gives the half cell potentials for Std Calomel Electrode (SCE) under standard conditions (Table 3) the values are however only a guideline, the potentials can vary in a wide range depending on the moisture of the concrete.

$Icorr = \dfrac{Uc - Ua}{Ra + Rc + RL}$	Icorr = Corrosion current, Uc = Open circuit potential at cathode Ua = Open circuit potential at anode Ra = anodic polarization resistance, Rc = cathodic polarization resistance, RL = electrolyte resistance of concrete.

The Icorr i.e the rate of corrosion (µm/year) would show an increase if either or both R_a & RL decrease.

The R_a (anodic resistance) is due to the passive film of Fe - hydroxide / oxides during the process of corrosion, the R_a decreases if this passive film is broken. Presence of chlorides decreases the R_a as it depassivates the steel (Table-1) and forms metallic hydroxides / oxides depending on the pH and availability of oxygen and water . These products increase the PBR ratio and results in expansive pressure. The Pilling & Bedworth ratio is the ratio of metal oxide volume to metal volume and used to predict whether or not the scale that forms will protect a metal from further oxidation. The PBR ratio > 1.4 is sufficient to cause cracking & spalling.

The electrolytic resistance of concrete (RL) (concrete resistivity) directly relates to the corrosion current (Hope & Alan[13]) the Table 2 gives general guidelines on resistivity values and probable corrosion risk in concrete structures.

Table: 2 Resistivity of concrete v/s Corrosion probability

Resistivity (ohm-cm)	Corrosion probability
> 20000	Negligible
10000 to 20000	Low
5000 to 10000	High
<5000	Very high

Table 3 State of corrosion as per ASTM C - 876 - 91

Potential (mV SCE)	State of Corrosion
More negative than - 270	Active
More positive than -220	Passive
- 220 to - 270	Active or passive
<5000	Very high

Table 1: Corrosion Causing Reactions in concrete

Agents	Reactions	Resultant effect
Oxygen	Anode: $2Fe_{(s)} \rightarrow 2Fe^{++} + 4e^-$ $2Fe^{++} + 4OH^- \rightarrow 2Fe(OH)_2$ Cathode: $2H_2O+O_2+4e^- \rightarrow 4OH^-$	Corrosion of steel. Formation of protective passive film of nano-meter thickness of iron hydroxide / oxides
Chloride	A) Without oxygen at anode $Fe(s)^+2Cl^- \rightarrow (2Fe^{++}+2Cl-) + 2e\ (2Fe^{++}+2Cl-) + 2H2O \rightarrow 2Fe(OH)2+2H^+ +2Cl-$ B) In presence of oxygen at anode $6(Fe+++2Cl-) + O^2 + 6H2O \rightarrow 2Fe_3O_4 +2H++2Cl-$ The Chloride acts as a catalyst in corrosion of steel and generates again to continue corrosion reaction C) Attack on hydrated pastes $Ca(OH)_2+MgCl_2 \rightarrow CaCl_2+Mg(OH)2CaO.$ $Al_2O_3+CaCl_2 + H_2O$ Friedel salt ($CaO.Al_2O_3.CaCl_2.10H2O$) Friedel salt Ettringite (in presence of $CaSO_4$) C-S-H + Mg→C-M-S-H	Chloride ions break the passivating film formed on steel External penetration causes differential concentration and sets up micro-cell. Presence of micro-cells increases electrical conductivity
CO_2	$Ca(OH)_2 + H_2O + CO_2 \rightarrow CaCO_3 + H2O$	Reduces alkalinity of pore increasing risk of corrosion. Releases more water
Sulphates	Discussed under resistance to sulphate attack	

Table 4 : Some physical characteristics of hydrated cement paste/concrete of OPC and fly ash based Blended cements

Cement type	Coefficient of Permeability (10^{-11} cm/sec) (Age: 180 days)	Av. pore Radius (°A) (Age: 90 days)	Chloride diffusivity (10^{-9} cm/sec) (Age: 90 days)	Electrical resistivity (k ohm-cm) (Age: 120 days)
OPC	8.70	240	24.5	13.14
Fly ash based Blended Cement	1.77	166	4.1	29.08

The parameters of concrete which directly or indirectly determine the rate of reinforcement corrosion are:

- Pore structure & permeability
- Chloride /oxygen diffusion coefficients
- Chloride binding capacity
- Electrical resistance parameters such as density and resistivity of concrete.

Tests carried out [15] on low lime Class-F fly ash based Blended cements with ~ 30 % fly ash, indicate that although the total porosity is more in the 90-day hydrated blended cement as compared to the OPC, the pores in the former are finer than the OPC. The average pore radius of the Composite cement was observed to be 166 °A as against 240 °A in the OPC. A comparison of coefficient of permeability of water and chloride diffusivity in OPC and blended cements is shown in Table-4;

The difference in the characteristics of the OPC and Fly ash based cements/concrete is attributable to the compacted, dense microstructure of the cement paste matrix of the fly ash blended cements.

The lesser permeability of the fly ash based cement / concrete prevents leaching of lime there by maintaining the concrete less porous and less permeable to oxygen and penetration of chlorides. The fly ash based cement/ concrete exhibit lower coefficients of chloride diffusion compared to Portland Cements. The imperviousness of the blended concrete prevents carbonation to the depths of the steel reinforcements there by maintaining the alkalinity in the vicinity of the steel rendering it passive from corrosion.

The presence of fly ash also reduces the free chlorides in the pore solution, as the fly ash hydrated products tend to bind the free chlorides (Friedel salt formation). The binding of the free chlorides is however a function of the C_3A content of the cement clinker used for the blended cement. The presence of higher levels of Friedel salt can be identified by DTA analysis .

Table 5 illustrates the unbound chlorides in pore solution in plain and fly ash blended cements when treated with different levels of chlorides. It has been observed that use of 30% fly ash reduces the free OH - ions in the pore solution from an average value of 260 mM/L (pH=13.41) to an average value of 205 mM/L (pH=13.31) for the

Table- 5 :Unbound chlorides in pore solution in plain and fly ash blended cements when treated with different levels of chlorides

% C_3A in Cement clinker	Cement Type	% Total chlorides addition	% Cl^- in Pore solution	Unbound chlorides (as %of Total Cl^-)
2.43	OPC	0.6	74.4	50.7
	FA-cement	0.6	44.1	33.9
	OPC	1.2	94.1	61.8
	FA-cement	1.2	64.4	49.3
14.0	OPC	0.6	18.1	11.6
	FA-cement	0.6	11.7	8.3
	OPC	1.2	38.4	24.4
	FA-cement	1.2	33.5	23.3

low C_3A cement while for the high C_3A cement solution, from an average value of 520 mM/L (pH=13.72) to an average value of 315 mM/L (pH=13.50) at all the chloride levels, resultantly the Cl^-/OH^- ratio is also reduced.

The effect of pore refinement, reduced chloride / oxygen diffusivity, reduced chloride mobility, is evident in the electrical resistance and the corrosion observed in the concrete. As expected the electrolytic resistance of concrete increases with time and fly ash incorporation levels. This is finally reflected in the corrosion initiation & Corrosion rate observed in the blended cement concrete. (Fig. 15 & 16).

The improvement in the corrosion resistance property with ground (Mechanically activated) fly ash has been reported by Saraswathy et al (16) (CECRI Karaiudi). Indicating the role of particle characteristics of fly ash in increasing the corrosion resistance of the steel reinforced concrete. In inter-ground fly ash based blended cements such a mechanical activation of the fly ash is achieved during the intergrinding process. As compared to OPC concrete, the fly ash based cement concrete, have higher elastic Modulus, higher Modulus of rupture and split tensile strengths (Fig.17 & 18). These properties would help over come the stresses caused and effectively increase the crack initiation time by corrosion.

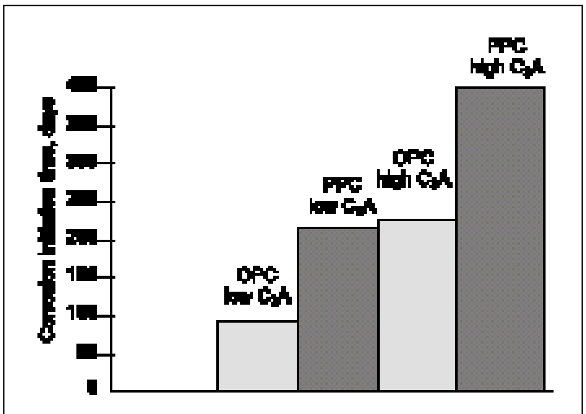

Figure 15: Corrosion initiation of steel in plain and fly ash blended concrete

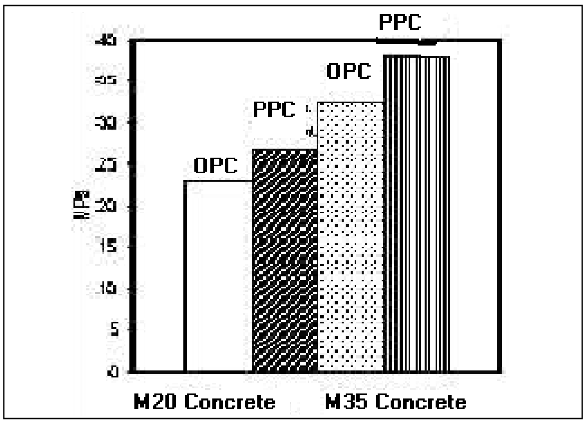

Figure 17: Comparative Elastic Modulus

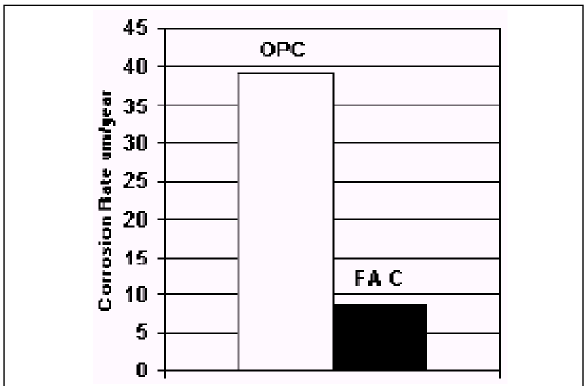

Figure 16: Corrosion rate of steel in OPC and fly ash blended concrete

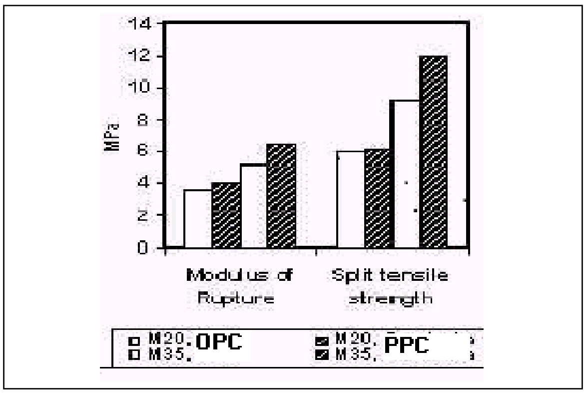

Figure 18: Modulus of rupture & split tensile

The hydration of tri-calcium aluminate (C3A) in Portland cement in presence of solubilised sulphate ions (from gypsum) results in formation of ettringite which is harmless as the concrete is still in semi-plastic state.

$C_3A + 3CSH_2 + 26H \longrightarrow C_6AS_3H_{32}$

Calcium aluminate Gypsum Water Ettringite

Sulphate attack is observed when structures are exposed to sulphatic environments such as sulphate bearing soils or ground waters causing an increase in volume of cement paste in concrete or mortar due to chemical reaction between hydration products of cement and solution containing sulphate ions.

The reactions take place in either or both of the following ways

$Ca(OH)_2 + Na_2SO_4.10H_2O \longrightarrow CaSO_4.2H_2O + 2NaOH + 8H_2O$

Calcium Sulphates Gypsum Hydroxide

$4CaO.Al_2O_3.19H_2O + 3(CaSO_4.2H_2O) \longrightarrow 3CaO.Al_2O_3.3CaSO_4.31H_2O + Ca(OH)_2$

Ca - aluminate Hydrates Gypsum Ettringite

The formation of gypsum and/or ettringite causes expansion and cracking or softening of the concrete

The sulphate attack can be from calcium, sodium, potassium or magnesium sulphates. The Magnesium sulphate has a more damaging effect because it leads to decomposition of the C-S-H as well as calcium hydroxide and hydrated calcium aluminate hydrates eventually forming hydrated magnesium silicates, which has no cementing properties.

The sulphate attack involves the calcium hydroxides and C3A and also depends on the effective permeability of the concrete to sulphate ions. Experimental data indicates that fly ash based cement concrete, especially those made with low calcium, Class-F fly ash are more resistant to sulphate attack than the PPC concrete made with high calcium Class - C fly ash and that the sulphate resistance is also a function of the fly ash incorporation levels. A relation evolved between the CaO/SiO2 ratio of fly ash and sulphate resistance of the concrete is shown in Fig.19(17). In 1980 Dunstans (18&19) summarized the results of studies on sulphate attack of fly ash concrete and proposed the use of resistance factor (R).

$R = (C-5)/F$

where C is the CaO and F is the Fe_2O_3 contents of the fly ash.

The selection of fly ashes (25% absorption levels) in terms of 'R' limits for sulphate resistant concretes are as follows:

'R' Limits (Fly ash)	Sulphate resistance *
< 0.75	Greatly improved
0.75 – 1.5	Moderately improved
1.5 – 3.0	No significant Change
> 3.0	Reduced
* Relative to ASTM Type II cement at W/C ratio of 0.45	

Figure 20 Illustrates the sulphate resistance of the concrete with fly ash of different 'R' values.

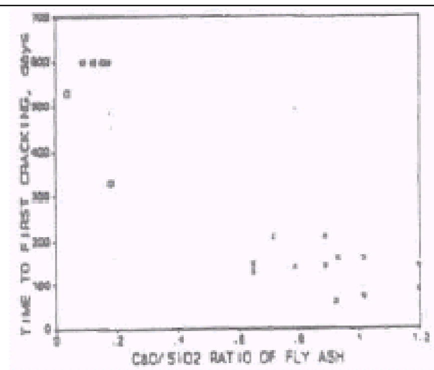

Figure 19: Sulphate resistance of concrete As a function of CaO/SiO2 ratio of fly ash

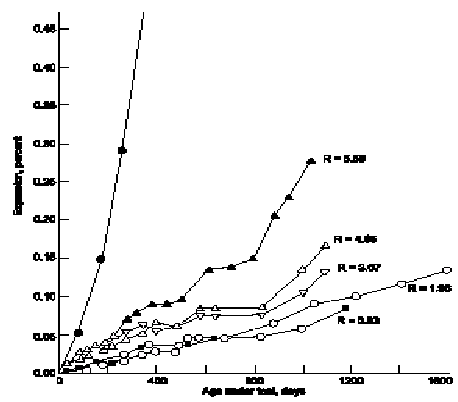

Figure 20: Sulphate resistance of concrete at different R - values of fly ash

These results indicate that the Low Lime class-F fly ashes available in country are chemico - mineralogically better suited for improved sulphate resistance of the resultant concrete.

3.6 Resistance to Alkali Silica Reation (ASR):

Alkalis in hardened concrete react with the reactive aggregates forming high volume gel products. Although the actual reactions are still to be understood completely the common accepted formations are summarised below:

Reactive silica + alkalis ----→ alkali silicates of aggregates

For Dolomitic Aggregates:

Reactive Carbonate + Alkalis Dedolomatisation ---→ Alkali Carbonates + Magnesium Hydroxide + Calcium Carbonate

The volume expansion linked with the formation of alkali silicate hydrate gels or the de-dolomatisation induces expansion and severe deterioration of concrete.

The aggregates and their mineralogical constituents known to react with alkali include the following:

- Silica materials - Opal / Chalcedony, Tridymite and Crystobalite
- Zeolites especially Heulandite
- Glassy to cryptocrystalline rhyolites, dacites andesites and their tuffs
- Certain Phyllites

The factors that effectively minimise the ASR reactions in a blended cement concrete can be summarised as follows (20 & 21).

- Use of fly ash in concrete show reduced expansion compared to control OPC concrete (Fig. 21).
- Low C/S ratio in the C-S-H fixes the alkalis through adsorption or solid solutions there by decreasing the alkali ion concentrations in the pore solution. Fig. 22 illustrates the relation between the C/S ratio of C-S-H and % alkali retained in the C-S-H.
- C-S-H formed in the secondary reaction of fly ash & $Ca(OH)_2$ fills up the pores in the hardened cement paste matrix suppresses the movement of in pore solution.
- Use of fly ash changes the zeta potential (22) making the surface of the pores in hardened paste positively charged there by suppressing the movement of the alkali ions in the pore solution.
- Composition of fly ash i.e CaO content of fly ash (Fig. 23).

Generally fly ashes with higher alkali or CaO contents are less effective in controlling the expansion due to ASR and consequently have to be used at higher replacement levels (Fig 24 illustrates the relation between the minimum safe replacement level and CaO+2Na2O/SiO2 ratio of fly ash).

Use of Low lime Class - F fly ash available in the country is compositionally more suited for resistance of concrete to ASR reaction. It may be noted here that minimum safe levels of fly ash thus would vary depending on the nature & reactivity of aggregates, available alkalis in concrete (from Cement), exposure conditions of the concrete and finally on the composition of Fly ash used.

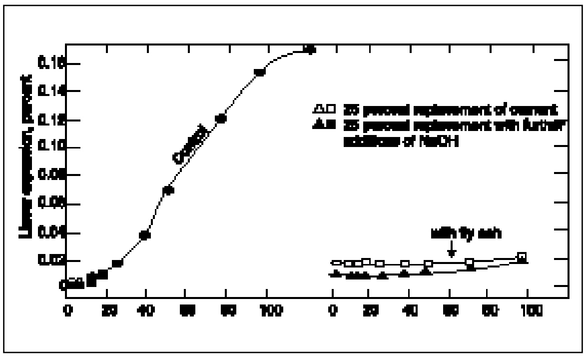

Figure 21: Expansion of concrete prisms made with reactive aggregates and 25% cement replacement with low lime Fly ash

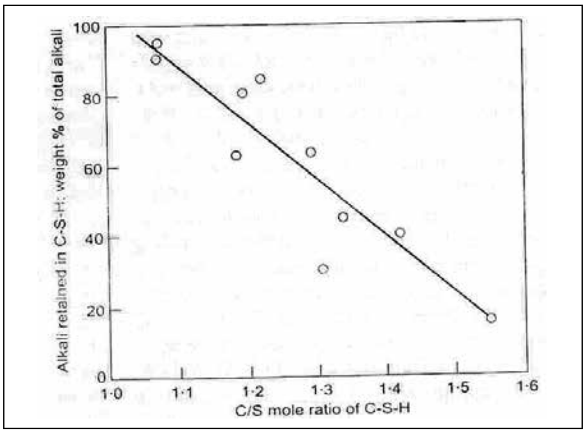

Figure 22: Relation between the % alkali retained in C-S-H and C/S ratio of C-S-H

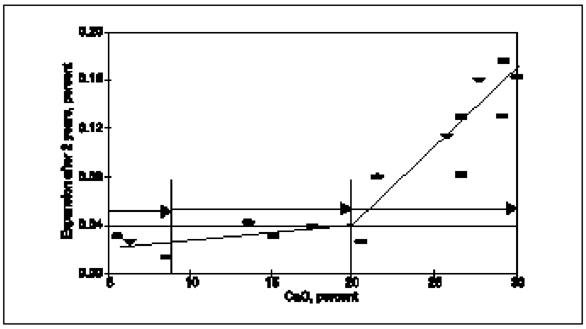

Figure 23: ASR expansion v/s %CaO Contents of fly ash

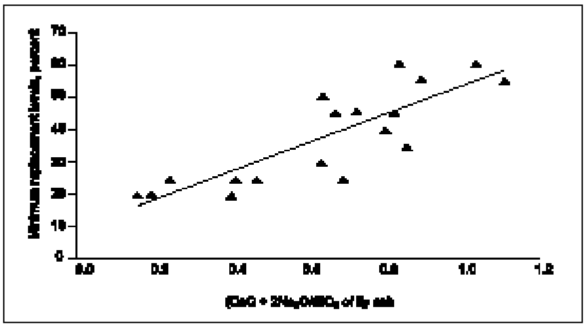

Figure 24: Minimum Replacement levels & $CaO+2Na_2O/SiO_2$ of Fly ash

CONCLUSIONS:

The aspects discussed in the paper illustrates that the low Lime Class-F fly ash available in the country are compositionally most suited for use in Blended cement /blended concrete for improving the resistance of the concrete to deterioration due to corrosion of steel reinforcements, Sulphate attack and expansion due to ASR reaction.

A proper understanding of the influences of the fly ash characteristics and with use of proper methods for reducing variability , improving its particle characteristics in the resultant cement can help to engineer the properties of the resultant blended cement for Durable Civil structure .

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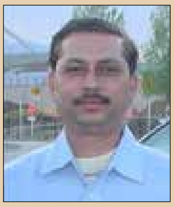

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TMT Reinforcement Bars In RCC Construction Basic Guidelines

Dr. N. V. Nayak

Preamble

Use of RCC construction is increasing day by day. In fact concrete is globally largest consumed material only next to water. With increasing height of structures, buildings, chimneys, cooling towers, there is substantial increase in steel reinforcement per cum of concrete.

Unfortunately, in India, many particularly developers use steel rebars produced from non-integrated steel process, as such steel is available at lower rates. Such steel should never be permitted in any structure other than temporary.

Paper also highlights higher density of steel per cum of concrete in tall structures which will result in lower bond and high possibility of corrosion of steel as noted in the paper.

Introduction

There are basically two distinct process of manufacturing steel rebars.

One is the sophisticated, mechanised process which ensures, high quality steel rebars and which is the process adopted by all developed countries. This process for simplicity is designated as "Primary" process.

The other is a primitive process adopted in developing countries like India. In this process quality control is highly limited or poor. This process for simplicity is termed herein as "Secondary". By the way, these terminologies are no more used in Indian Codes. But these terminologies are used herein for simplicity.

Attached Table 1 indicates limitation of secondary rebars. Hence, from quality and durability consideration, such Secondary Steel Rebars should never be used. Fortunately, practically all government agencies prohibit use of such reinforcement bars. Since developer do not come under the government or any autonomous body these bars are used by many developers including for high rise buildings. It is given to understand the use of Secondary Steel Bars in India is quite high and close to 50%.

Table -1

Parameter	Rebar from Non-integrated Steel Company Termed as "Secondary Manufacturers"(*)		C] Rebar from Integrated Steel Company Termed as "Primary Manufacturers" (*)
	A] Re-rollers	B] Induction furnace operators	
Process Brief	Converts scrap (input dimensions of scrap suitably selected keeping the final dimension of re-rolled rebar in mind into rebar by simply reheating and rolling to final shape. Very remote possibility of heat-wise traceability. No melting facilities, hence no control on steel making.	Converts the scrap into rebar by melting, casting and rolling. Inherently, the batch sizes are small so both compositional and property variations within the supplied batches (of a considerable size) vary. Heatwise traceability is difficult due to too low heat size (10-25 ton).	Beginning from virgin Iron Ore (many a times from self owned mines)and using BF (Blast furnace) and BOF (Basic oxygen furnace) and Continuous casting route, re bars are produced. Good heat size (150 - 250 ton) and heatwise traceability maintained in final product.
Process control ability	Poor: Manual control, Poorly maintained equipment, Safety and Environmental unfriendly As the input material billet/ ingots / thicker size scrap (ship breakage / rejected slab) tracebality with respect to heat, chemistry and quality conformance is impossible. Control on Input material quality is very far below requirement.	Poor: Manual control, Poorly maintained equipment, Safety and Environmental unfriendly. Much smaller heat size with much less automation. Due to lack of process control, steel cleanliness is also very poor.	Very Good: Process models assisted production, Technical tie-ups with world's leading technology providers for keeping pace with the latest technology, Highly trained staff, R&D back up. Level of process control is far above requirement as per IS standard.

Main Raw material input Refining capability: Steel cleanliness	Scrap: Usually from non-standard sources - heterogeneous in composition. No control as no melting/refining facility.	Scrap: Usually from non-standard sources - heterogeneous in composition. Poor: The refining kinetics, directly related with the temperature of the melt, suffers because the ability to attain the temperature in induction furnace does not compare with the LD or, EAF (Electric arc furnace). Phosphorus removal ability of Induction furnace is very poor so the entire phosphorus content of charged scrap is passed on to the final composition of rebar. Secondary refining, responsible for lowering the melt's Sulphur content and cleanliness control, usually attained in Ladle furnace, is not available.	Basic minerals like Iron Ore, Coal (quality depends upon process), fluxes etc. No purchased scrap, but internal scrap is generally used. Very Good : By selection of better raw material, Hot Metal can be of good quality for direct use in Steel Melt shop. If not, by pre-treatment HM is desulphurised before sending to Steel Melt Shop (SMS). In SMS (BOF/ EAF furnace – primary steelmaking), desiliconisation & dephosphorisation are done. Modern furnace are having eccentric tapping mechanism to ensure slag-free tapping to Ladle , which is transferred to secondary refining facility like LF. Extensive de-oxidation, desuplphurisation with inert gas purging + cored wire feeding makes very clean & homogeneous killed steel within very restricted chemical composition as per IS standard & Mill requirement.
Casting	No facilities & hence not applicable	Poor: Usually cast in static moulds which produce ingots/ billets with severe and serious casting flaws (Central pipe, Central segregation, Blow holes etc) which are simply passed onto the finished rolled rebars. Some of the manufacturers deploy continuous casting but without any modern facilities to aid good quality billet production.	Very good: 100% metal cast through continuous casting route. These casters are equipped with Closed casting facility and equipped with Electro-magnetic stirrer in the moulds. The cast billets are homogeneous across its cross-section and along its length which when rolled produces homogeneous rolled rebars with respect to chemistry and properties.
Thermo-mechanical treatment	Poor: Deploys local cheap indigenous but unreliable arrangement for cooling the bars. As a result the uniformity of tempered martensite (hard rim) is absent. In many instances tempered martensitic layer is completely absent. Partial tempered martensitic layer of the rebar makes it vulnerable to inherent galvanic corrosion. (Fig.1)	Poor: Deploys local cheap, indigenous and unreliable arrangement for cooling the bars. As a result the uniformity of tempered martensite (hard rim) is absent. In many instances tempered martensitic layer is completely absent. Partial tempered martensitic layer of the rebar makes it vulnerable to inherent galvanic corrosion and also poor control of mechanical properties. (Fig.1)	Excellent: Patented Thermex or, Tempcore processes are deployed to ensure an uniform rim formation around the periphery of the rebar. Computer aided control of the cooling not only ensures that cooling is reliable for each of the rebar but it also comes handy in manufacturing rebars with different end property requirements such as Super-Ductile, Higher strength (Fe600) etc. (Fig.2)
Chemical composition control of final product	No control: Input scrap's composition is the composition of the rolled rebar's composition. Usually, the selection of input scrap is price and size dependent which does not take into account the chemical composition.	Poor: The input Scrap's quality (chemical composition) dictates the end product's compositional state thereby, making it vary from batch to batch.	Excellent: Post steelmaking in BOF or, EAF - almost an hour long secondary refining treatment is practiced for the chemical composition control of melt. Several mid-treatment samples are collected and analysed for assuring the precise compositional control before it is cast.

Property control: Strength	Partial or, uncontrolled tempered martensitic layer results in unreliable and unpredictable strength and corrosion properties of the rebar.	Partial or, uncontrolled tempered martensitic layer results in unreliable and unpredictable strength and corrosion properties of the rebar.	Excellent: An all round process control and strict adherence to equipment maintenance schedules by qualified professionals - the MACRO properties (Rim and Core) are controlled which in turn ensures that the strength properties are always adhered to.
New Product Development (higher strength – Fe650 / Fe700 as per IS 1786 revision proposal & requirement for high rise building)	Not possible	Poor R&D facilities & Process Control capability to produce higher strength steel.	Excellent R&D facilities and few integrated steel plant have already developed this product and waiting for release of revised standard of IS 1786 to launch these 2 products in Market. Such critical application grade should be procured from only those plants, where process control is robust & reliable.
Property control: Ductility	Poor: Excessive cooling: a result of poor process control and excessive quenching, results in rebar's that exhibit very high strength but very low ductility.	Poor: Both composition (Carbon, Sulphur and Phosphrous) and TMT process control dictate the ductility properties of the rebar. Usually, both lack and variable controls of these (varying amongst the lots and manufacturers) have been observed which consequently reflects in big fluctuations in the ductility properties of the rebar produced through this route.	Excellent: An all round process control and strict adherence to equipment maintenance schedules by qualified professionals - the MACRO properties (Rim and Core) are controlled which in turn ensures that the ductility properties are always adhered to.
Property control: Corrosion resistance property	Poor: Poor refining (i.e. higher residual contents) and TMT process results in intrinsically poor corrosion property of rebar produced through this route.	Poor: Poor refining (i.e. higher residual contents) and TMT process results in intrinsically poor corrosion property of rebar produced through this route.	Excellent: By virtue of the control of both composition (i.e. residual contents such as Sulphur and Phosphorous) and MACRO constituent (i.e. concentric Tempered martensitic layer on the periphery) - the corrosion properties are observed to be very good.
Surface defects	Rerollers generally take diverted billets / ingots. None of the ingots / billets are checked for surface and internal soundness. Defects in billets / ingots are passed into finished goods	Due to raw material from different sources / scrap, raw material quality is not the same. This leads to surface defects and poor internal soundness of billets / ingots.	Billets / slabs are checked for surface defects and internal soundness. Defects, if any, are salvaged / rejected as scrap. This ensures defect free TMT bars.
Mechanical testing for the finished goods	Due to lower heat size the amount of sampling required is very high. Testing charges will also be high. Variation in mechanical properties from lot to lot will also be very high.	Same as A	Due to bigger heat size the amount of sampling required is very less, testing charges will also be less, variation in mechanical properties will be minimum.
Use in Developed Countries	Not Used	Not Used	Used
Approximate cost of production plant	15 Crore for 0.1 million ton production per annum	Rs.130 cr for 0.1 million ton production per annum	Rs. 8000 cr per one million ton production per annum

(*) These terminologies used for convenience

Figure 1 : Typical MACRO response of Non Integrated Steel Company (Secondary)

Figure 2: Typical macrostructure of Rebar of Integrated Steel Plant (primary)

Steel Rebar Congestion

More and more high rise buildings are constructed in India. Many of these buildings are higher than 300m. It is observed that in Core wall of such buildings, reinforcement can be very dense even of the order of 0.5 to 0.6t per cum. (Refer Table-2 and Fig.3). With such heavy reinforcement, spacing of rebars does not meet codal requirement either of the American code ACI 318 or European code EN 1992 - 1-1 or Indian code IS 456. As a result, quite often, cover to reinforcement is not concrete, not even mortar, but just a slurry, thereby permitting steel rebars for early corrosion. Moreover, bond developed will be far less which may result in unsafe building during heavy wind. It may be noted that wind speed is increasing year by year. Hence, it is very advisable to go for higher and higher grade of steel rebars to reduce its congestion. At present, we in India are able to manufacture steel of grade upto and including Fe 600. We should permit manufacturing of Fe700 or even higher grade of rebars by early approval of relevant code.

Table 2: Denisity of Rebars in Concrete in Corewall of Tall Buildings in Mumbai (Height more than 150m)

Name of the Project	**Height (m) (Approx.)**	**Steel (kg/cum)**
(A)	153	320
(B)	203	220
(C)	280	462
(D)	284	515
(E)	429	590

Figure 3: Impurities in Steel Rebars

Table 3: Limit of sulphur and phosphorus in different standards of rebar (Indian/ International)

Product	Standards	Sulphur (max)(%)	Phosphorus (max) (%)	Sulphur+ Phosphorus (max)(%)
Rebars India	IS-1786-Fe 500	0.055	0.055	0.105
	IS-1786-Fe 500 D	0.040	0.040	0.075
	Tata Tiscon Fe 500D	0.035	0.035	0.070
Rebars USA	ASTM A 706	0.045	0.035	Not mentioned
Rebars Japan	JIS-G3112 (SD-490 grade)	0.040	0.040	

Table 4: Limit of Sulphur and phosphorus in high rise building projects in Japan

	Tensile strength/ MPa	Yield point(YP)/ MPa	Chemical component (%)					
			C	Si	Mn	P	S	Cu
USD685A	≥YP/0.85=1.176 YP	685-785	≤0.50	≤1.50	≤1.80	≤0.030	≤0.030	≤0.050
USD685B	≥YP/0.80=1.250 YP	685-755	≤0.50	≤1.50	≤1.80	≤0.030	≤0.030	≤0.050
USD980	≥YP/0.80=1.250 YP	≥ 980	≤0.80	≤1.20	≤2.00	≤0.030	≤0.030	≤0.050

C = Carbon, Si = Silica, Mn = Magnesium, P = phosperous, S = Sulphur, Cu = Copper

Conclusion

1. It is essential we use steel rebars manufacturered by "Primary Players" and not to use steel rebars manufacturered by "Secondary Players" unless it is an unimportant or temporary structure.
2. It is very desirable to restrict contents of sulphur and phosporous each to less than 0.03% particularly for high rise buildings. For other buildings we may use steel rebars meeting the codal requirements w.r.t. these impurities. However, steel rebars with lower percentages of impurities of 0.03% or less for each sulphur and phosphorous are always preferable.
3. When designing the RCC structures it is very desirable to meet the codal requirements w.r.t. spacing of bars etc.
4. Use of higher strength steel bars is always preferable to reduce congestion of steel paritcularly in high rise buildings. At present in India upto and including Fe600 rebars are manufacturered. It is desirable that higher strength bars are manufactuered for high rise buildings to reduce congestion.
5. In high rise buildings, if it is difficult to a certain extent to avoid congestion of rebars, it is very desirable to specify self compacting concrete to avoid honey combing and to achieve proper compaction.

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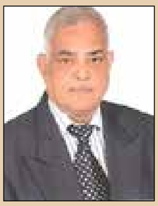

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Assessment of Carbonation Depth under Natural and Accelerated Carbonation Conditions

Shaik Hussain, Dipendu Bhunia and S.B. Singh

This paper deals with the effect of accelerated carbonation on mechanical properties and durability of unreinforced concrete. Concrete with water binder ratios of 0.35, 0.50 and 0.65 were cast and kept in accelerated carbonation chamber under controlled conditions for a period of 1 year. Specimens were removed at predefined time intervals and tested for compressive strength, flexural strength, modulus of elasticity, volume of permeable pores and depth of carbonation. The depth of carbonation obtained from the accelerated carbonation conditions are used to predict the carbonation depths under natural concentration of carbon dioxide using Fick's law and the values are compared to those obtained from a structure 60 years old.

Introduction

Concrete as one of the basic construction materials, is likely to withstand aggressive environments and maintain its durability without hindrance. But being a porous material, it is susceptible to ingress of various substances through its interconnected capillary pores. When carbon dioxide (CO_2) from atmosphere comes in contact with the hydration products of cement, it changes the physical and chemical properties of the concrete. This process is termed as carbonation of concrete [1-3].

Carbonation is a physiochemical process, which involves the diffusion of carbon dioxide in the gaseous phase of the concrete pores and the dissolution of CO_2 in the pore water as carbonic acid (H_2CO_3). It constitutes the formation of HCO_3- and CO_3^{2}-ions and the dissolution of hydration products of cement such as $Ca(OH)_2$to release Ca^{2+} and hydroxyl ions and the formation of $CaCO_3$ [4]. This reaction of $Ca(OH)_2$ is considered to be the most responsible reason for the reduction of the pH value of the pore solution of the concrete [5] which being around 12.6-13 is observed to fall to less than 9[6]. This fall in the value of pH is held responsible for the initiation of depassivation phenomena of rebar embedded in the concrete, further exposing the rebar to potential corrosion threats. This is called carbonation-induced corrosion. Therefore it is extremely crucial to study the carbon dioxide ingress in concrete in accordance to the duration of exposure to predict the time taken by the products of carbonation to reach the rebar.

Though the process of carbonation of reinforced concrete, in terms of durability proves to be a malady, it is likely to improve the mechanical properties of unreinforced concrete. Because the carbonation product $CaCO_3$ has higher molar volume than that of $Ca(OH)_2$ and C-S-H, a decrease in porosity is evident [4]. This decrease in porosity may improve the mechanical properties such as compressive strength, flexural strength, split tensile strength and modulus of elasticity of the carbonated concrete. It is to be noted here that, only surface porosity of concrete is decreased under carbonation [7-9]. The reason for which may be explained because the ingress of carbon dioxide is limited to a certain depth.

The factors that mainly influence the rate of carbonation are type and amount of pozzolanic material, the water binder ratio, the porosity of the material, the moisture in the vicinity and the duration of curing [10,11]. Amongst all the above-mentioned factors, the amount of moisture plays a principal role in governing the kinetics of carbonation. A low relative humidity dries up the concrete capillary pores and makes it difficult for the carbon dioxide to enter the pores irrespective of how porous the medium is. On the contrary high relative humidity condense the water in pores of concrete and delays carbon dioxide diffusion. Therefore for ideal conditions of carbonation, the relative humidity is to be maintained between 50-70% [12, 13].

The atmospheric concentration of carbon dioxide is 0.03-0.04% by volume. This considerably less concentration of carbon dioxide is the reason why the process of natural carbonation takes more than a decade to initiate [14]. To predict the long-term performance of concrete after natural carbonation, the process can be accelerated either by increasing the concentration of carbon dioxide in the vicinity or by increasing the atmospheric pressure [5]. Though few researchers still debate about how reliable the results of accelerated carbonation are in comparison to the natural process, Yongsheng et al., [14] proposed that the results of micro-structural analysis of natural and accelerated carbonation showed same phase compositions and similar XRD peak intensities.

This paper deals with the experimental investigation on the compressive strength, flexural strength, modulus of elasticity, volume of permeable voids and depth of carbonation of the unreinforced concrete exposed to accelerated carbonation for up to 1 year. To study the behavior of water binder ratios on the carbonation of concrete, water binder ratios of 0.35, 0.5 and 0.65 are adopted. Further, from the laws of diffusion, and the depth of carbonation obtained from the accelerated carbonation conditions, depth of carbonation under natural exposure conditions are predicted and compared with results obtained from the experimental investigation from a structure that is subjected to degrading natural environment for 60 years.

Experimental Program

Materials

Ordinary Portland cement (Grade 43) was used in the present experimental program, the chemical compositions of which are listed out in Table 1. The physical characteristics of the cement are given in Table 2. Crushed basalt with a specific gravity of 2.77 was used as a coarse aggregate and sand as fine aggregate has a specific gravity of 2.42. The size of coarse aggregates were in a range of 12.5 to 20 mm while fine aggregates were in a range of 0.075 to 4.75 mm. Water reducing admixture has been used to attain a slump of 100±20 mm to make the concrete workable. Its specific gravity was found to be 1.08. Concrete mix proportions for the various mixes used are presented in Table 3. The specimens were kept in carbonation chamber for 7, 28, 60, 120, 180, 240, 300 and 365 days after moist curing for 29 days. After the process of accelerated curing, the specimens were removed and tested for their predestined experiments. These results are compared to concrete specimens associated with 7 and 28 days of water curing.

Carbonation environment

To compensate the process of natural carbonation, which normally takes few decades, the concrete, specimens are subjected to high amounts of carbon dioxide in a controlled environment. The concentration of carbon dioxide was fixed to 5% and the relative humidity ranged from 50% to 70%. The temperature of the chamber in which the specimens were kept was maintained at 25oC to 35oC.

Tests procedure

To evaluate the carbonation effects on mechanical properties of concrete, several experiments such as compressive strength, flexural strength and modulus of elasticity were performed. Depth of carbonation and volume of permeable voids were also measured to study the durability aspects of carbonated concrete. To measure the compressive strength and volume of permeable voids, concrete cubes of (15×15×15) cm3 were cast, flexural strength, depth of carbonation and modulus of elasticity were measured by casting prisms of (10×10×50) cm, (15×15×90) cm and cylinders of 30 cm height and 15 cm diameter respectively. They were then removed carefully from moulds and placed in water for an age of 28 days. Once the process of water curing was accomplished, the specimens were removed from water and dried in air for a day (temperature being 40oC) and kept in carbonation chamber after cleaning with a dry cloth. After the requisite duration of curing, the specimens were removed from the chamber and tested.

Tests for compressive and flexural strengths were carried out using the methods suggested in IS 516 [15]. The test for modulus of elasticity includes the testing of cylindrical specimen under axial compression and measuring the strain.

Depth of carbonation was measured by spraying phenolphthalein pH indicator. The indicator is a phenolphthalein 1% ethanol solution with 1 g phenolphthalein and 90 ml ethanol diluted in water to 100 ml [16]. The carbonated zone, where Ca(OH)2 is converted to CaCO3, remains colorless and the zone where the value of pH was above 9.5, turns purple in color. Volume of permeable voids was measured by the method suggested in ASTM C642 [17]. The concrete specimens once removed from carbonation chamber were kept in oven for 24 hours and weighed. This process was repeated until the difference between two successive readings was within 0.5% of the lesser weight. The specimens were then immersed in water for 48 hours and weighed after its surface was dried. The readings were taken till the difference between the readings was less than 0.5%. After this the specimens were subjected to rigorous boiling for 5 hours and then weighed after 14 hours. Finally the specimens were suspended in water and their apparent weights were taken. The calculation of volume of permeable voids (%) was done by the formulae mentioned in ASTM C 642 [17].

To validate the results obtained from the predicted values of depth of carbonation under natural carbon dioxide exposure, depth of carbonation was found for a building that was subjected to environmental concentrations of CO_2 for 60 years, and rigorous change in climatic conditions with the temperature ranging from 48oC during month of June to 1oC during December.

Experimental Results and discussions

Mechanical properties

Influence of age of carbonation

The compressive strengths, flexural strengths and modulus of elasticity for different duration of carbonation of each mix proportion curing are shown in Figure 1 (a - c) respectively. From the figures it is perceived that the accelerated carbonation has some beneficial effects on concrete. These mechanical strengths increased with an increase in the duration of accelerated curing. The increase in compressive strength, flexural strength and modulus of elasticity for 365 days of accelerated curing over an age of 28 days water curing is remarkable. This increase may be accounted for the greater volume of $CaCO_3$ over $Ca(OH)_2$.

Influence of water binder ratio

The results shown in Figure 1 demonstrate the compressive and flexural strengths and modulus of elasticity of the three types of concrete mix designs used in the present experimental study. The concrete mix proportion with highest water binder ratio has shown least mechanical strength compared to the other mixes. This decrease is particularly adamant in concrete mix proportion with the water binder ratio of 0.65.

Durability

Volume of permeable voids (%)

The test results for the volume of permeable voids are presented in Figure 2. As shown in the figure, the percentage of voids has decreased with the age of accelerated carbonation. The drop is highest for the concrete mix with the least value of water-binder ratio.

Depth of carbonation

The depth of carbonation is the measure of the depth till which CaCO3 has formed. From Figure 3, it is evident that the depth of carbonation has increased with age of accelerated carbonation. The depth of carbonation is observed to be highest in the concrete mix proportion with highest water binder ratio. It is because of the decrease in compressive strength and open pore structure that makes the concrete with highest water binder ratio have highest the depth of carbonation.

Prediction of Carbonation Depth for Environmental Exposure

To understand the kinetics of carbonation in real life, i.e., for an exposure of concrete to natural concentration of carbon dioxide (0.03- 0.04%), it would take more than a decade to completely comprehend the study, which is why increasing the carbon dioxide concentration, accelerating the process contemplates it.

Though results from accelerated carbonation tests have been used to predict the carbonation depths on long-term natural exposures [5], there still lies a conjecture on how to extrapolate the real performance from accelerated tests [18-20]. This is certainly a complex phenomenon because the natural exposure conditions differ greatly from the controlled accelerated conditions where the humidity and temperature are maintained constant. This predominantly changes the mass transfer properties [21].

It is a well-established directive that the carbonation depth progresses with duration of exposure. Nevertheless the rate of carbonation decreases with time and is usually considered proportional to square root of exposure time [5]. This assumption holds good even in the case of accelerated carbonation exposure.

This can be well explained by Fick's second law of diffusion in which the diffusion causes the concentration to change with time. Assuming a uni-directional flow the partial differential equation can be written as,

$$\frac{\partial \phi}{\partial t} = D \frac{\partial^2 \phi}{\partial x^2}$$

where D is the diffusion coefficient (m2/s), is the concentration (g/m3), t is time (s) and x is the position [carbonation depth in (m)].

Usually, the progression of carbonation depth is considered as the square root model of time. The equation was first proposed by Tuutti [22] and was written as,

$$x = k\sqrt{t}$$

where x is carbonation depth, t is duration of exposure and k represents coefficient of carbonation.

The coefficient of carbonation can be determined by another approach theoretically, which uses the first law of diffusion. Fick's first law of diffusion relates the diffusive flux to the concentration under the assumption of steady state. It states that the flux goes from regions of high concentration to regions of low concentration, with a magnitude that is proportional to the concentration gradient. In one (spatial) dimension, the law is given by the following equation.

$$J = -D\left(\frac{\partial \phi}{\partial x}\right)$$

where J is the diffusion flux (g/m^2.s).

Upon further simplification of Eq. (3) and relating the expression k in terms of concentration, the rate of carbonation can be written as, [23,24]
where k is rate of carbonation (m/s0.5) and m is amount of CO2 required to react with alkali

$$k = \sqrt{\frac{2D\emptyset}{m}}$$

phases (g/m3) contained in unit volume of sample. Assuming the values of Dand mas sample properties constants for each concrete, a relationship of carbonation coefficients can be generated in terms of carbon dioxide concentrations. Thus the ratio of coefficient of carbonation for accelerated and natural conditions can be expressed as,

$$\frac{k_{acc}}{k_{nat}} = \frac{\sqrt{\emptyset_{acc}}}{\sqrt{\emptyset_{nat}}}$$

where and are carbon dioxide concentrations in natural and accelerated exposure conditions respectively.

A linear relationship between and has been assumed in the literature review [25,26]. The ratio of carbonation coefficients of both accelerated and natural conditions from Eq. 2 can be related to those of the theoretical values obtained from the Eq. 5. To rationalize the above assumption, survey of literature has been done to find any relation that considers the theoretical and practical carbonation coefficients on a single platform. Khunthongkaew et al., [27] in his research exposed the concrete samples for a carbon dioxide concentration of 4% by volume, where the ratios of carbonation coefficients of accelerated and natural carbonation, under experimental evaluation and theoretical formulae differed by 4.29%. Ohga et al., [28] in a similar research when exposed the concrete to carbon dioxide concentration of 7%, kept indoor, the ratios differed by 3.81%. Chin[29] considered the carbon dioxide concentrations of 7% and 12%, and deduced the ratios of carbonation coefficients under both conditions. He found that the ratios have had a deviation of 1.62% and 5.02% respectively for the concentrations.

Figure 4 (a-c) shows the depth of carbonation and coefficient of carbonation for water binder ratios adopted in the present paper. The predicted values for coefficient of carbonation under natural exposure conditions are determined by equating the ratios obtained from Eq. 2 and Eq. 5. The depth of carbonation in accordance to these carbonation coefficients is plotted in Figure 5, which shows the predicted depth of carbonation every 10 years for a period of 60 years.

It is evident from the Figure 5 that the depth of carbonation is least in the concrete with water binder ratio 0.35; where as a marginal difference in depth of carbonation of concretes with water binder ratios of 0.50 and 0.65 is observed. 60 years of concrete exposure to natural concentration of carbon dioxide (0.03%-0.04%) yielded a depth of carbonation of 46 mm for a water binder ratio of 0.65, which was attained in 60 days under accelerated carbonation conditions.

The results of depth of carbonation found for a building with an age of 60 years is tabulated in Table 4. Drilling a cylindrical core of diameter 75 mm and spraying phenolphthalein indicator found the depth of carbonation.

As no information has been found on the field about the grade of concrete and water binder ratio involved during the construction of the structure, it is not possible to determine the water binder ratio that we could relate to the accelerated conditions. Given the Indian code of practice at that time, the water binder ratio is presumed to be between 0.45-0.50.

The depth of carbonation obtained from the predicted values by equating Eq. 2 and Eq. 5 for a water binder ratio of 0.50 as seen in Figure 5 for 60 years is 40mm.But the original maximum value for the depth of carbonation from Table 4 has been found to be 30 mm. The depths of carbonation predicted from the accelerated conditions adhere to the controlled conditions of temperature and humidity where as the structure when exposed for 60 years to the natural carbon dioxide and the weather, withstands varying temperature and humidity. This explains the difference in the values of depths of carbonation. The other reason for this difference might be because of the relatively lower R2 value for the equation of depth of carbonation in Figure 4(b).

G) Conclusions

Unreinforced concrete when exposed to higher carbon dioxide concentrations increases its surface porosity, whichin turn enhances its mechanical properties. Concrete with three water binder ratios 0.35, 0.50 and 0.65 were used to test for their mechanical strength and durability. It is observed that the compressive strength, flexural strength and modulus of elasticity have increased with the duration of the accelerated carbonation exposure. The depth of carbonation too, as expected has increased. It is highest for the concrete with a water binder ratio of 0.65. Volume of permeable voids has reduced with the duration of exposure, owing to the decrease in surface porosity. The depth of carbonation under natural concentration of carbon dioxide is predicted for an age of 60 years for the accelerated tests using laws of diffusion. The depth of carbonation for a structure 60 years old has been obtained and compared to the predicted values. It is observed that the values differ in its magnitude, which might be explained because of the controlled conditions of accelerated curing chamber, whereas the structure exposed to natural environment has no such restraints.

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Table 1. Chemical composition of cement

Chemical composition	OPC 43 grade (%)
SiO2	20.27
Al2O3	5.32
Fe2O3	3.56
CaO	60.41
MgO	2.46
SO3	3.17
Loss on ignition	3.55

Table 2. Physical characteristics of cement

Physical Characteristics	OPC 43 grade
Density (kg/m3)	3090.15
Specific gravity	3.15
Fineness (%)	8
Normal consistency	33

Table 3. Design mix proportions of concrete

Mix proportions for 28 day strength of 30-35 MPa in kg/m^3				
Water binder ratio	Cement	Water	Fine Aggregate	Coarse Aggregate
0.35	450	157	557	1088
0.50	394	197	655	1125
0.65	304	197	734	1114

Table 4: Depth of carbonation of 60 years old structure

Floor	Elements / Locations	Depth of Carbonation (mm)
Ground Floor	Columns	17
	Beams	22
	Ceiling Slabs	26
1st Floor	Columns	23
	Beams	30
	Ceiling Slabs	26

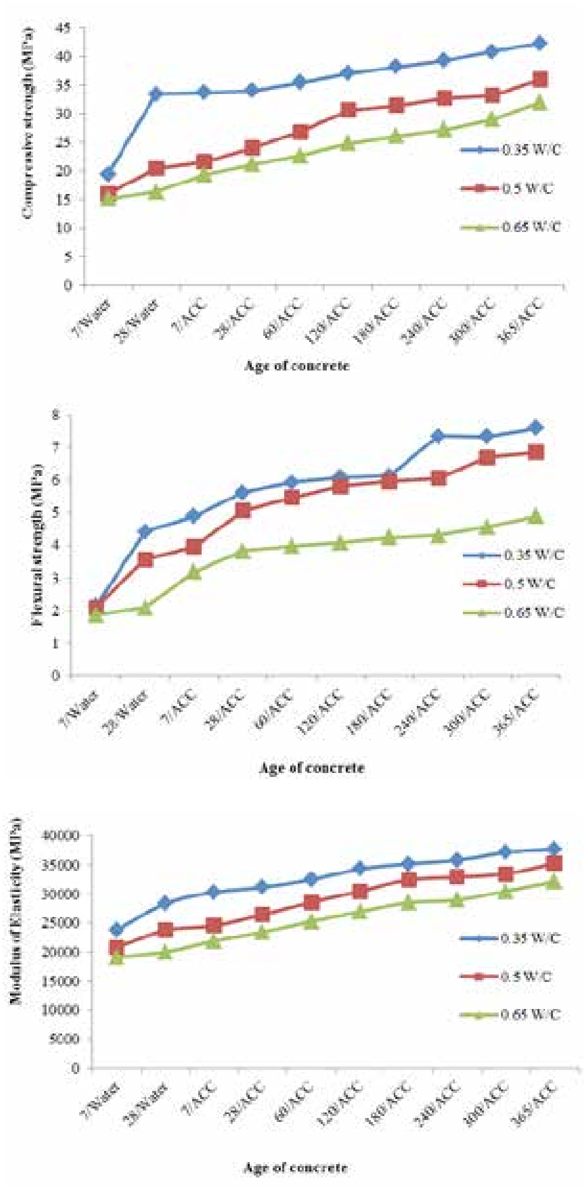


Fig.1 Mechanical properties vsAge of concrete

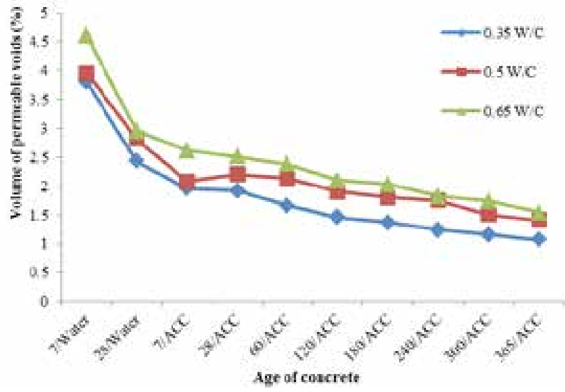


Fig.2 Volume of permeable voids vsAge of concrete

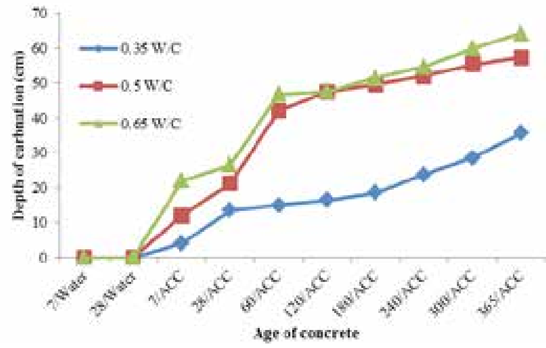
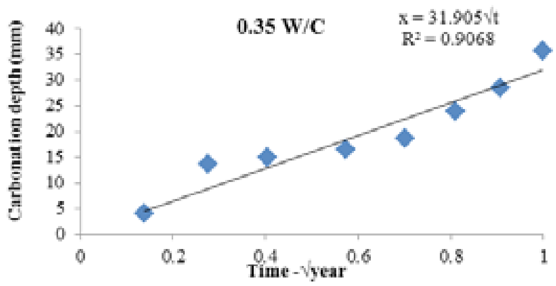
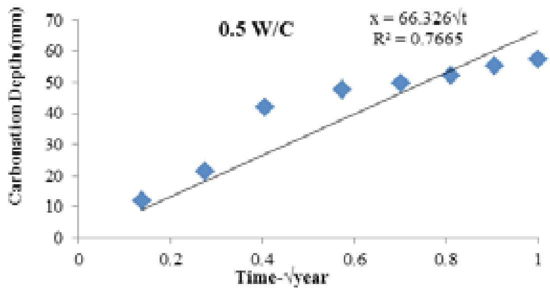


Fig.3 Depth of carbonation vsAge of concrete





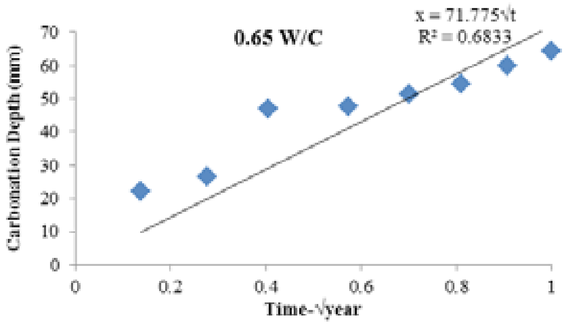


Fig.4. (a-c) Carbonation depth vs Time

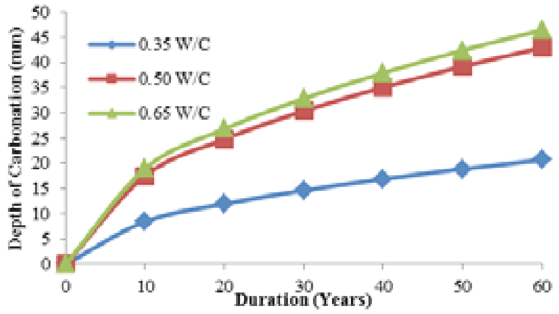


Fig. 5 Predicted depth of carbonation depth under environmental exposure to CO_2

Shaik Hussain

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BIM (Building Information Modeling)

Ms. P. Solomon

Building information Module refers to technology which helps architects, engineers and construction industry for planning, estimation and execution of building project in most efficient way. Most of the BIM related software incorporate following features or more.

BIM is a new approach of "Virtual Building Construction" based on parametric CAD technology. Simply it implies that before actual building is made, first make its virtual model on computer. With help of software first view the building in totality. Find out that if there are any clashes, determine the sequence of construction, work out material & manpower required at every stage and plan accordingly.

In the current scenario, most of the architects and engineers makes 2D drawings. Different elevation and sections are drawn independently on different set of drawings. Problem with this approach is that if any of component is changed then consultants has to go to all the drawing and work out changes manually. While in BIM approach complete 3D Model is made and different views are derived from 3D Model. Whenever changes are there they are automatically reflected in all the drawings.

BIM Software

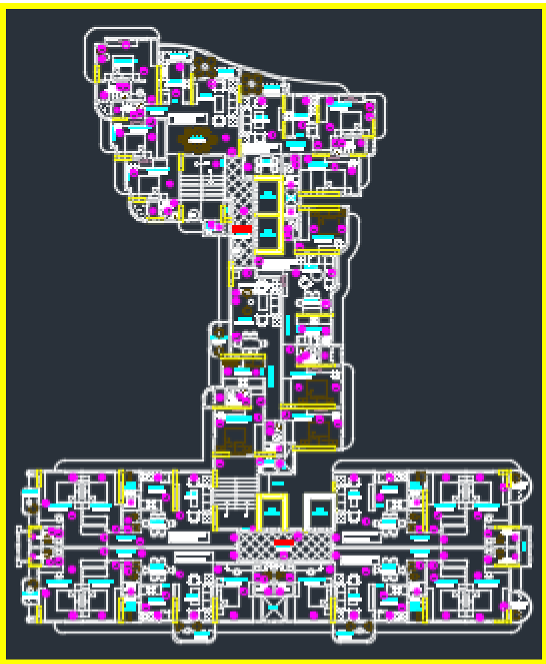
There are different software's based on BIMPlatform; Autodesk Revit Building (Revit), ArchiCAD, Bentley, and SolidWorks are among few. In India one of the most popular software used is Autodesk Revit which is a group of three software REVIT Architecture, REVIT Structure & REVIT MEP. As mentioned earlier most of consultants create 2D Drawing. BIM Consultants converts these drawing to 3D Model. One of the problem faced by BIM consultants is that rarely architect drawings and structure drawing matches completely. Usual practice is that construction is carried out as per architect drawing on which sizes of structure components like beam, column, shear wall and slab is super imposed.

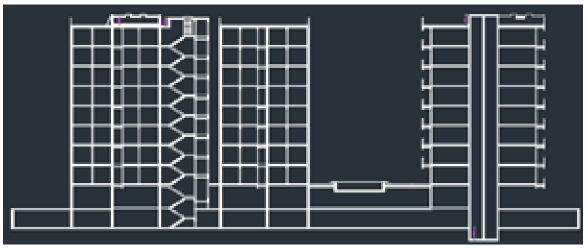
In all BIM software, all the entities are object with intelligence. For example, window or door can only be placed on walls. Also with object database is associated. So information like manufactures or cost etc. can be obtained along with schedule which can be generated from model. When model gets modified so also schedule along with costing. This greatly reduces chances of error.

One another featured is worth mentioning is ability to describe construction sequence. In your model, you can specify which are the item which is already cast, or you can decide which items will be cast along which time interval. This can be greatly useful under new provision of RERA initiated by Indian Government. Architect / Structural engineer can mark all the items constructed during particular period, for which given the rate automatically total cost is worked out which can be linked on web site for particular project.

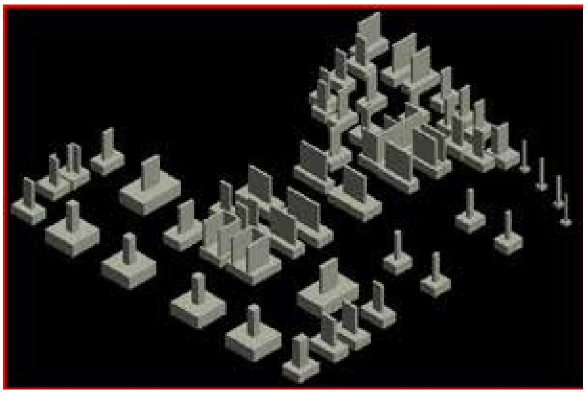
Author of this article Ms P. Solomon has carried out number of project for leading architects and builders. She has also conducted number of corporate training abroad and India. Following article explains how the prestigious project in Mumbai was carried out from detail generated using BIM model and how it helped builder to arrive at exact quantities required floor wise and procure the material accordingly. Also, it helped in clash detection which avoided breaking of beams during placement of electrical & plumbing fixtures.

For the following project necessary, architectural and structured drawing were provided by client. Based on footing size 3D model of footing layout was generated using BIM software. Quantity and BBS (Bar bending schedule) was automatically generated based on 3D Model.





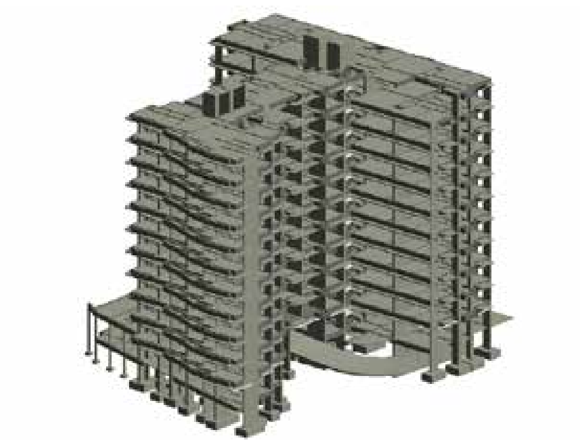
Architectural and structural drawing provided by client become basis of generateing 3D Model



		FOUNDATION LEVEL		GRADE - M35	
DESCRIPTION (FOOTING)	LENGTH (MM)	WIDTH (MM)	HEIGHT (MM)	VOLUME (M3)	SHUTTERING (M2)
F1	2800	1800	1000	5.04	9.20
F2	3600	1600	1400	18.14	20.16
F3	3600	1600	1400	18.14	20.16
F4	3600	1600	1400	18.14	20.16
F5	3700	1700	1400	15.17	20.72
F6	2700	2200	1000	5.94	9.80

Footing quantities generated thru software

From the 2D drawing 3D model of all structural element was generated.

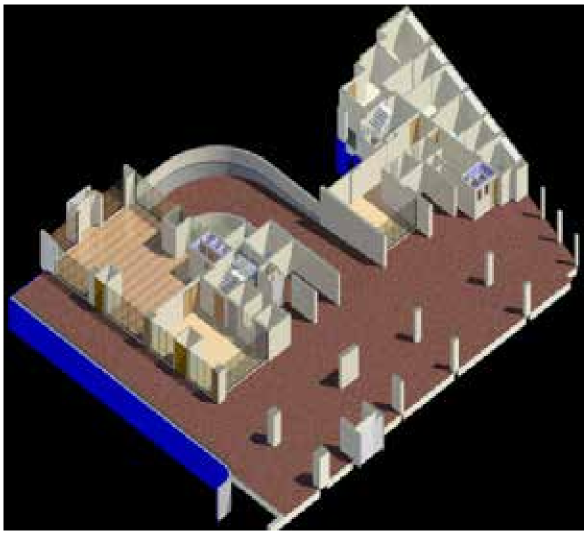


Summary of all concrete items

Total Of All Floors				
Description	Concrete	Unit	Shuttering	Unit
Column	1011.93	M3	8103.47	M2
Beam	988.13	M3	8001.29	M2
Slab	1344.27	M3	8893.08	M2
Footing	386.07	M3	586.2	M2
Ramp	70.23	M3		M2
Rcc Pardi	386.07	M3		M2
Raft	453.35	M3		M2
Filling	620.37	M3		M2
Waterproofing	2422.49	M2		M2
PCC	2859.79	M2		M2

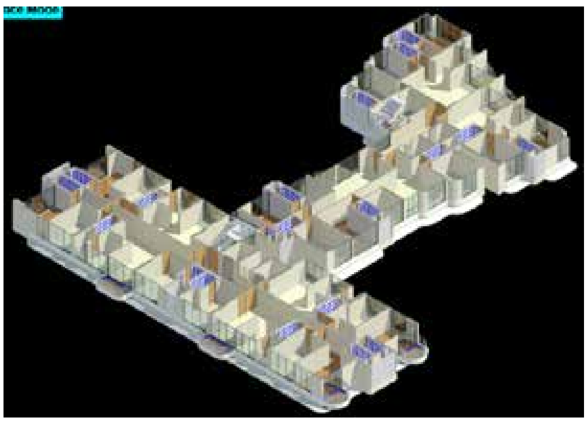
Next architectural drawing was superimposed on structural drawing to generate 3D view of the whole building as shown below

3D Architectural Model



Different view for all the floors were generated as shown below

Views showing water proofing, Ramp walls , floor finish including columns



View of Typical floor

LEVELS	ROOM DESCRIPTION	MATERIAL NAME	COUNT	AREA (M2)
	FLOORING			
BASEMENT	LOBBY	TILE	1	14.93
	BASEMENT	CHECKERD TILE	1	1375.71
	RAMP	CHECKERD TILE	1	234.09
	STAIRCASE	MARBLE	2	32.48
				1657.21
GROUND FLOOR	ENTRANCE LOBBY	MARBLE	2	103.49
	MULTIPUPOSE HALL	TILE	1	132.89
	ROAD & PARKING	CHEKERD TILE	1	700.82
	SHOPS	TILE	6	86.42
	METER ROOM	TILE	2	22.06
	SOCEITY OFFICE	TILE	1	22.34

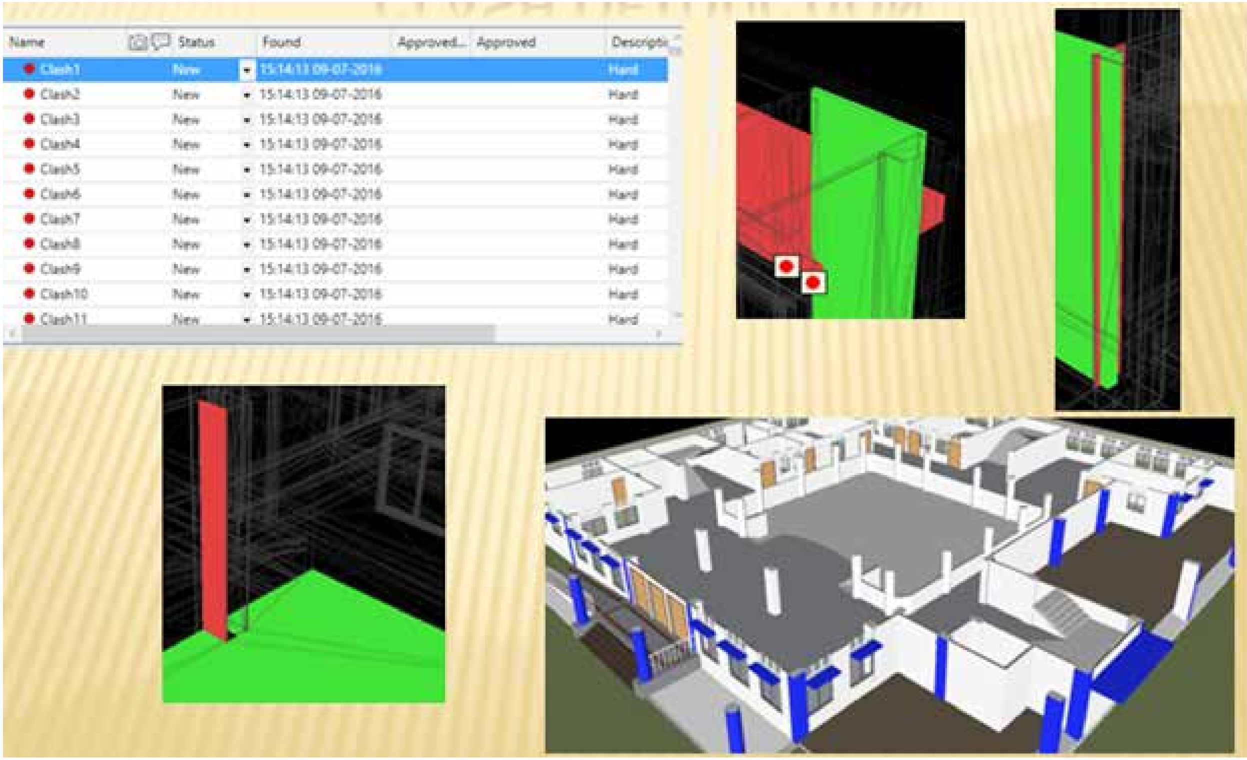
Flooring Quantities for all the items are generated directly from 3D model.

WALL							
DESCRIPTION	FLOORS						
THICKNESS	MATERIAL NAME	UNIT	BASEMENT	GROUND FL	1ST FLOOR (PODIUM)	2ND TO 10TH FLOOR	TERRACE
150MM	BLOCK	M2	78.25	573.65	784.95	7064.55	265.13
TOTAL NO. OF BLOCK	(600X200)	NOS	652	4780	6541	58871	2209
SIZE OF BLOCK	0.12						
						Total	2475
12MM	INTERNAL PLASTER	M2	1509.8	2051.52	2432.01	21888.09	775.94
TOTAL NO.OF BAGS	CEMENT	NOS	302	410	486	4378	155
TOTAL NO.OF BAGS	SAND	NOS	1208	1641	1946	17510	621
	INTERNAL PAINT	M2	1139.29	2004.41	2431.46	21883.14	774.83
						Total	774.83

Quantities for Wall (Including number of blocks of different size)

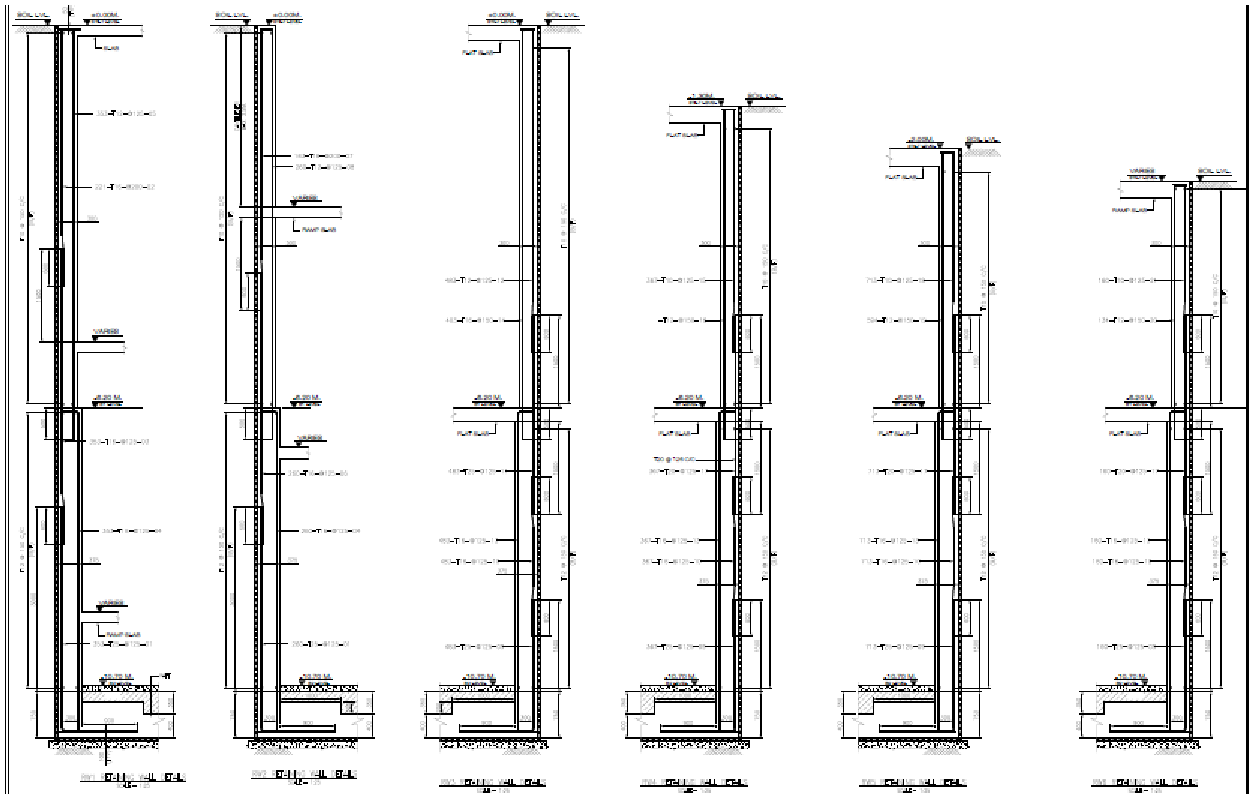
SUMMARY (BLOCKS, CEMENT & SAND)			UNIT (NOS)
LEVELS	BLOCKS (NO.)	CEMENT (BAGS)	SAND (BAGS)
BASEMENT	652	302	1208
GROUND FLOOR	4780	508	2061
1ST FLOOR	6541	678	2765
2ND TO 10TH	58871	6098	24885
TERRACE	2209	341	1415
TOTAL	73054	7927	32334

BIM model is shared between different disciplines like architect, Resolving conflict: Next all the conflicts were resolved by superimposing Architectural, Structural & MEP drawing. Besides graphically showing location of conflicts it also gives information on tabular format



Bar Bending Schedule: along with BIM module, BBS for all the structural element is also provided.

Retaining Wall



Bar Bending Schedule for Beams

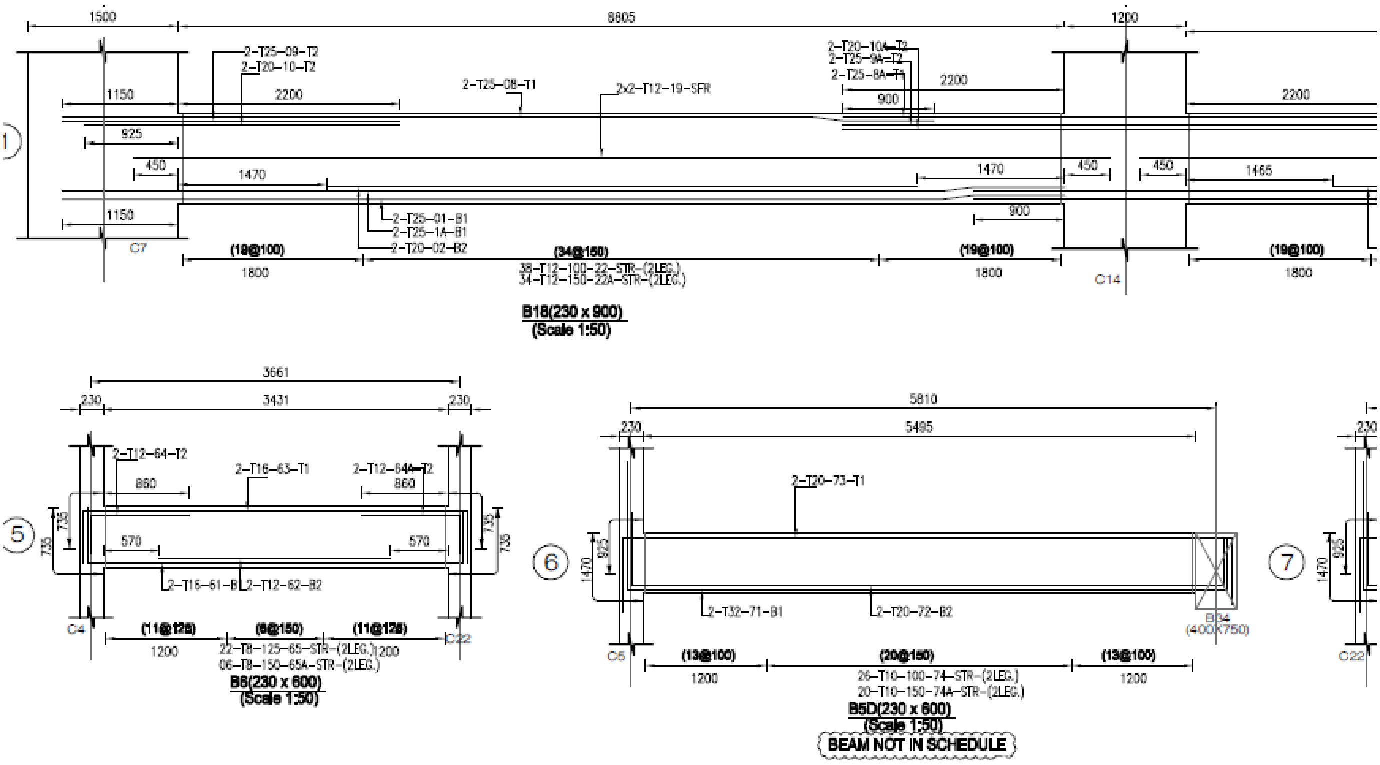
Member	Bar mark	Type and size		No. of mbrs	No. in each	Total No	Len of each bar † mm	Shape code	A * / F * mm	B * / G * mm	C * / H * mm	D * / I * mm	E/R * / J * mm	Weight (Kg)	Shape
FOUNDATION BEAM REINFORCEMENT DETAILS															
FB5 (250 X 1000) NEAR GRID (1 BET C-D)															
B1	01	T	20	1	3	3	6000	21	475	4650	875			44.44	A B C
T1	02	T	20	1	3	3	6000	21	455	4690	855			44.44	A B C
FB	03	T	12	1	6	6	4600	0	4600					24.53	A
STR	04	T	10	1	27	27	2370	51	190	875	120	120		39.50	A B
STR	05	T	10	1	27	27	1165	22	120	875	50	120		19.42	A B D C

Bar Bending Schedule for Columns

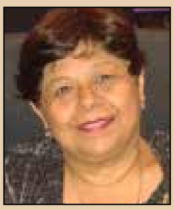
Column Desc	Stage	Bar Type	Member	No. in each	Total No	Len of each bar † mm	Shape code	A * / F * mm	B * / G * mm	C * / H * mm	D * / I * mm	E/R * / J * mm	Weight (Kg)	Shape
C-1,4,23,37,40,57,80,	1	Main	1	5	195	5890	11	300	5590	0	0	0	2835.93	A B
	1	Main	2	5	195	7190	11	300	6890	0	0	0	3461.85	A B
	2	Main	3	5	195	5654	26	1000	280	4374	46	0	2722.30	A B C
	2	Main	4	5	195	5654	26	1000	280	4374	46	0	2722.30	A B C
	3	Main	5	5	195	4063	34	1000	224	2039	37	800	1252.01	A B D C E

Bar bending schedule for slab

Slab No	Member	Bar Mark	Type	Size	No. of Mbrs	No. of bars in each	Total No.	Spacing	Length of bar (mm)	Shape Code	A/F (mm)	Weight (Kgs.)	Shape
SEL-1	A	01(a)	T	8	1	1	1	200	4235	20	4235	1.67	A
	A	01(b)	T	8	1	1	1	200	3890	20	3890	1.54	A
	A	01(c)	T	8	1	1	1	200	3545	20	3545	1.40	A



Ms. P Solomon



She has worked extensively on BIM platform for a number of years and is Qualified Professional for Autodesk Project. She has imparted training to number of corporates houses, consultants and colleges, India and abroad.

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Performance of Fibre Reinforced Concrete: Human Hair as Fibre

Anand Kumar, Govardhan Bhatt and M. Mumu

Abstract

Fibre reinforced concrete can offer a convenient, practical and economical method for overcoming micro-cracks and similar type of deficiencies. Since concrete is weak in tension hence some measures must be adopted to overcome this deficiency. Human hair is strong in tension; hence it can be used as a fibre reinforcement material. Hair Fibre (HF) an alternate non-degradable matter is available in abundance and at a very cheap cost. It also creates environmental problem for its decompositions. Experiments were conducted on concrete beams and cubes with various percentages of human hair fibre i.e. 0%, 0.5%, 1%, 1.5% by weight of cement. For each combination of proportions of concrete one beam and three cubes are tested for their mechanical properties. By testing of cubes and beams we found that there is an increment in the various properties and strength of concrete by the addition of human hair as fibre reinforcement.

Key words: Fibre, Strength, X-ray diffraction, Human hair

Introduction

Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of which lends varying properties to the concrete. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities. Fibers are utilized in cement to manage the cracking characteristics and reduce permeability. The surrounding concrete protects the steel used for reinforcement. Glass fiber reinforced concrete is used for architectural products and steel fibers are mostly used for paving and inside tunnels.

Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion, and shatter–resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment-resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete.

The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" (Vf). Vf typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fiber's modulus of elasticity is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers that are too long tend to "ball" in the mix and create workability problems (Johnston Colin D., 2001).

Hair as Fibre in Fibre Reinforced Concrete:

Hair is used as a fibre because

1. It has a high elasticity which is equivalent to that of a copper wire with comparable width.
2. Hair, a non-degradable matter is making an ecological issue so its utilization as a fiber fortifying material can minimize the issue.
3. It is additionally accessible in wealth and with ease.
4. It fortifies the mortar and keeps it from spalling (Ahmed S. et. Al., 2011)

Fig. 1(a) Hair Length of 15mm

Fig. 1(b) Hair Length of 60mm

Testing And Results

The methodology adopted to test the properties and strength of hair reinforced concrete is governed by:

i. Slump Test
ii. Compressive Strength,
iii. Flexural Strength

Various cubes and beams are tested and analysed for finding the effect of using hair as fibre reinforcement with the following specifications.

Grade of cement used: 43 Grade OPC (Ordinary Portland Cement)
Water Cement Ratio used: 0.45
Grade of concrete: M25 concrete made by nominal mix design taking the ratio 1:1:2 (cement: fine aggregate: course aggregate)

Course aggregate: 10 mm aggregate and 20 mm aggregate taken in the ratio of 1:2
Fine aggregate: Sand with specific gravity 2.67
The specimens for compression and flexural strength tests were made in the following manner:

i. Compression test: Three cubes are made for each M-25 concrete with 0%, 0.5%, 1%, 1.5% hair by weight of cement.
ii. Flexural Strength test: One beam is made for each M-25 with 0%, 0.5% hair by weight of cement to analyze the performance in presence of fibre and in absence of hair.

Slump Test

In this test fresh concrete is filled into a mould of specified shape and dimensions, and the settlement or slump is measured when supporting mould is removed. Slump increases as water-content is increased. For different works different slump values have been recommended

Table 1: Slump Value for different hair content

% Hair	Slump Value (mm)
0%	92
0.5%	86
1%	83
1.5%	78

Compression Test

It is the most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test is carried out on specimens cubical in shape as shown in figure of the size 150 × 150 × 150 mm. The test is carried out in the following steps: First of all the mould preferably of cast iron, is used to prepare the specimen of size 150 × 150 × 150 mm. During the placing of concrete in the moulds it is compacted with the tamping bar with not less than 25 strokes per layer. Then these moulds are placed on the vibrating table and are compacted until the specified condition is attained. After 24 hours the specimens are removed from the moulds and immediately submerged in clean fresh water. After 28 days the specimens are tested under the load in a compression testing machine.

S.No.	% Hair	Compressive stress (N/mm2)		
		Cube No. 1	Cube No. 2	Cube No. 3
1	0%	25.33	25.11	26.0
2	0.5%	29.55	28.88	30.22
3	1%	31.55	32.0	30.667
4	1.5%	35.55	34.88	33.77

Flexure Strength

After 28 days the specimen is taken out from the curing tank and placed on the rollers of the flexural testing machine as shown in figure 2. Then the load is applied at a constant rate of 400 kg/min. The load is applied until the specimen fails, and the maximum load applied to the specimen during the test is recorded.

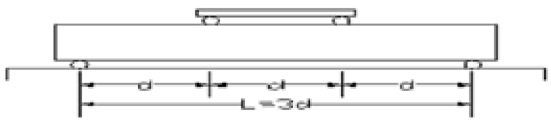

Figure 2: Test set up for flexure

S.No.	% Hair	Maximum Load Recorded (KN)	Flexure Strength (N/mm2)
		Beam	Beam
1	0%	8.5	3.1875
2	0.5%	9.0	3.7500
3	1%	10.0	3.9275

Conclusions

According to the test performed it is observed that there is remarkable increment in properties of concrete according to the percentages of hairs by weight of in concrete. The following conclusions were drawn:

- Slump value reduces as the percentage of hair reinforcement is increases.
- When concrete with 0.5% hair is compared with the plain cement concrete, it is found that there is an increase of 15.98% in compressive strength and 5.88% in flexural strength.
- When concrete with 1% hair is compared with the plain cement concrete, it is found that there is an increase of 23.25% in compressive strength and 17.64% in flexural strength.
- When concrete with 1.5% hair is compared with the plain cement concrete, it is found that there is an increase of 36.33% in compressive strength and 35.29% in flexural strength.

From the above, it can be seen that the hair reinforcement will improve the strength properties of the conventional concrete.

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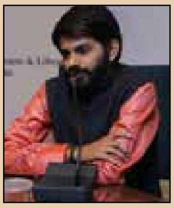


Author received his Ph.D in 2014 from IITROORKEE, India. He is working as an Assistant Professor in NIT Raipur for more than three years. He is having 4 Years of Experience in the field of Seismic Base Isolation RC Framed Structures. His area of expertise includes: Structural Dynamics, Geotechnical Engineering, Earthquake Engineering, Modeling, Vedic Studies, etc..

Published many peer reviewed national and international journal and conference papers.

Mr. Anand Shekhar

Author received his B. Tech in 2015 from NIT Raipur.

He is presently seeking for higher education.

QUESTION ??

If column concrete is M-40, and beam slab concrete grade is M-25. how to fill the Column beam junction and columns are going to next story?

Reply

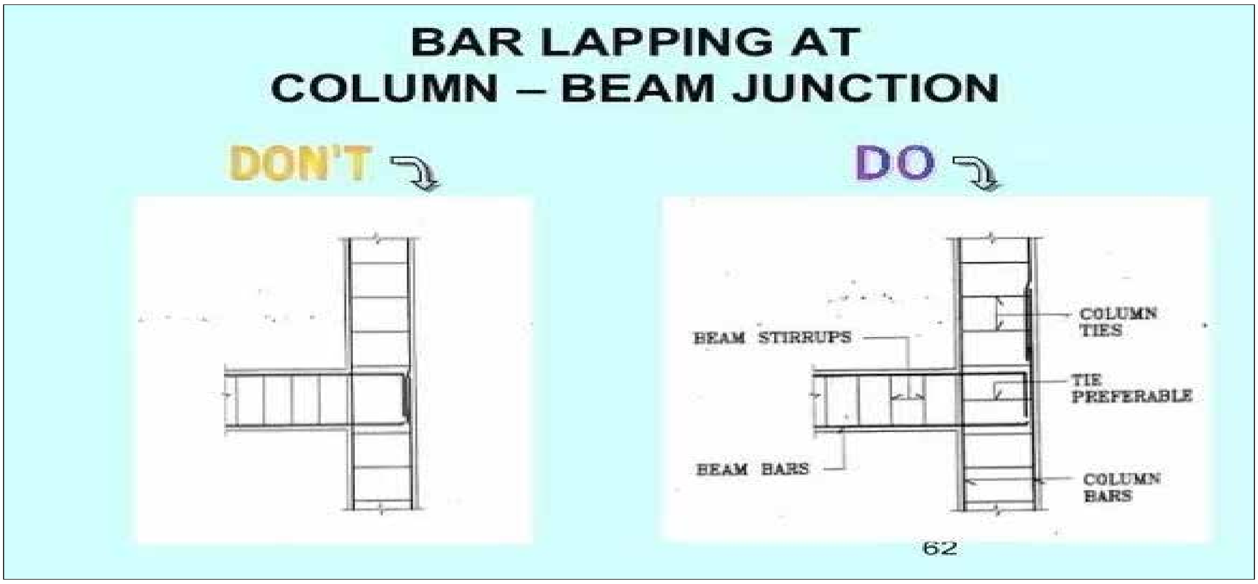
Fill up the column in M40 grade prior to filling slab and beams in M25. Let the column concrete flow in to beam.

Allow angle of repose. Also use stoppers in Beam and slab while concreting columns. This process may be followed wherever difference in concrete grade is is to be followed. Why ??!!

Column-Beam Junction ...Very important but sometimes importance not considered while concrete pour.

Beam is designed for forces at face of column. Therefore, beam-column junction is a part of the column and not the beam. Therefore it should be high strength. Beam-column junction is the weakest zone (especially in seismic loading) so this portion should always be detailed with caution.

by Shyju Nair, Cochin



Note: Requesting to send your questions for experts reply on the below mail id:
ambuja.technicaljournal@ambujacement.com

Participation in B2B Exhibition and partnering one day seminar, Mumbai

World Build India has organized a B2B exhibition for the building industry during 20th -22nd April 2017 at Bombay Exhibition Centre, Mumbai It was to showcase building materials, architectural engineering innovations and technologies that appeal to the key specifiers and influencers. It was targeted at Architectural, Structural, Mechanical, Electrical & Plumbing professionals. Apart from Exhibition there was a full day conferences on 21st and 22nd April 2017, the theme of the conference was "Engineering for the State of the art built environment" and on 22nd April, the theme was "Innovations in Structural Design & Construction". We showcased Integrated solution elements - Me tools, AKC , CFL & Microfine products. We have partnered the conference on 22nd April, 2017 on the theme "Innovations in Structural Design & Construction". The event was curated by Dr. Deepali Hadkar, Director, Sterling Engineering Consultancy Services Pvt Ltd, Mumbai.

Speakers are of very high calibre and the event has added good value to the practicing structural consultants

Outstanding Performance by ICI Raipur Centre through AKC

In the governing council meeting of ICI at Delhi, AKC Raipur and it's support for regular ICI programs were highly appreciated by ICI President Sh. M. Kalgal and President elect Vivek Naik in the forum. AKC Raipur efforts are also praised through email for outstanding performance under the guidance of Secretary Mr. Anurag Sullerey and Chairman Mr. Uttam Chand Jain for conducting maximum number of activities through AKC platform. The centre has organised 15 no of technical lecture programs in 2016-17 covering 440 professionals since formation in March 2016. Also 800 Contractors were trained on skill development and 300 contractors were taken for Ambuja Cement plant visit. Also Chairman of Raipur centre Mr. Uttam Chand Jain has been appointed as jury for "ICI outstanding concrete structure award 2017"

Highrise Building Design Workshop, Nagpur

Two day workshop module for professionals on "Advanced RCC (High-Rise) Building Design" was organized at Nagpur. 36 senior consultants from different parts of Vidarbha participated in the workshop. Expert speakers Er. Prakash Bajaj, Er. Abhishek Waghmare and Dr. Nadeem (TSH-W&S) from Mumbai shared their knowledge on Advanced RCC Design with the participants. Site visit was also arranged for observing raft foundation of High-rise Building (G+16) site of OM Shivam Buildcon, at Mihan. Er. P S Patankar briefed about the project and accompanied at site.

On Mon, Jul 17, 2017 at 6:28 AM, Vivek Naik <vivek.naik@applechemie.com> wrote:

Dear Shri Uttamchand Jain and Anurag

Good going . Keep it up .

Regards

Vivek Naik
President Elect

---------- Forwarded message ----------
From: **Anurag Sullerey** <iciraipurcenter@gmail.com>
Date: Fri, Jul 14, 2017 at 11:07 AM
Subject: ICI Raipur center -Activity Report 2016-17
To: ICI <ici4@airtelmail.in>
Cc: sukanta.paith@rmcindia.com, Uttam Chand Jain <uttam.bai@gmail.com>

To,
Sh.S.Radhakrishnan
Secretary
ICI,Chennai

Sub: ICI Raipur center activity report 2016-17
Dear Sir,

ICI Raipur Center since its formation in March'16 has been consistently engaged in knowledge sharing through knowledge sharing platform of Ambuja Cements .
The center has so far organised 15nos. of Technical Lecture programs in 2016-17 coering 440 professionals .

Also nearly 800 Contractors were trained on Skill Development and 300 contractors were taken for Ambuja Cement Plant visit .
I therfore request you that Raipur center be nominated as best ICI center pan India.

Pl. find attached the details of activities done at the center .

Thanks and Regards,
Anurag Sullerey
Secretary

Concrete pumping in high rise structures - Ambuja Knowledge Centre Kolkata

Organized a technical lecture on high rise pumping at AKC Kolkata. Regional head of Schwing Stetter (India) was the main speaker along with his national manager, Participants were delighted after the program. Total 35 participants from L&T, SPCL, KMDA, M N Dastur, Stup Consultant etc. participated

Answer of Quiz 4 in ATJ 4 issue

Kindly reply the below quiz and send it on the mail id. ambuja.technicaljournal@ambujacement.com

Question: 4

1) The technique for establishing and maintaining priorities among the various jobs of a project, is known

✓ a) Critical Ratios Scheduling
b) Event Flow Scheduling Technique
c) Slotting technique for scheduling
d) Short Interval Scheduling

2) Pick up the PERT event from the following:

a) Digging of foundation completed
b) Laying of concrete started
c) Laying of concrete completed
✓ d) All of the above

3) Time and progress chart of a construction, is also known as

a) Gantt Chart
b) Critical path method chart
c) Modified milestone chart
✓ d) All of the above

4) In long and short wall method of estimation, the length of long wall is the centre to centre distance between the walls and

✓ a) Half breath walls on both sides
b) Breath of the wall.
c) One fourth breath of the wall on both side
d) None of these

5) An aggregate is said to be flaky if its least dimension is less than

a) 1/5th of the dimension
b) 2/5th of the dimension
✓ c) 3/5th of the dimension
d) 4/5th of the dimension

ANSWERS

1 (a) Critical Ratios Scheduling
2 (d) All of the above
3 (d) All of the above
4 (a) Half breath walls on both sides
5 (c) 3/5th of the dimension

ATJ - 5 Quiz Corner

A) Technical Quiz

1. Recycled aggregate has a tendency of ___________ absorption.
   a. Higher
   b. Lower
   c. No difference

2. The maximum size of coarse aggregate used in concrete has a direct bearing on the _________ of concrete.
   a. Durability
   b. Economy
   c. Performance
   d. Electrolysis
   e. Electrochemical
   f. Electromechanical

4. Workability of concrete is directly proportional to
   a) Aggregate cement ratio
   b) Time of transit
   c) Grading of the aggregate
   d) All of the above

5. A beam curved in plan is designed for
   a) Bending moment and shear
   b) Bending moment and torsion
   c) Shear and torsion
   d) Bending moment, shear and torsion

Quiz: b) Word Search

Arrange to find 6 words which describes various types of cocnrete.

1. ....

2. ....

3. ....

4. ....

5. ....

6. ....

WS 5

H	H	E	M	C	S	T	T	S	A	C	C	L	N
I	S	E	H	G	E	N	T	R	H	T	E	F	U
G	L	L	I	G	L	N	A	I	O	E	T	E	H
H	H	T	G	L	F	A	N	H	T	N	O	Y	T
D	E	A	H	H	C	T	I	C	P	H	U	T	H
E	C	G	S	A	O	N	I	D	P	E	U	I	E
N	H	U	T	I	M	C	P	E	S	N	M	S	H
S	S	O	R	A	P	S	I	H	N	S	S	N	N
I	A	H	E	H	A	S	I	H	O	U	T	E	A
T	H	O	N	G	C	C	I	S	L	S	N	D	H
Y	S	G	G	M	T	E	A	S	M	A	P	W	I
H	I	S	T	H	I	E	O	A	I	A	A	O	A
T	I	H	H	N	N	I	T	I	D	C	I	L	Y
W	W	E	S	E	G	H	N	U	A	T	A	O	G

Reply for the above may be sent to email ID:
ambuja.technicaljournal@ambujacement.com

Guidelines & Information for Paper Submission

This guide describes sharing of technical paper to our Email id. ambuja.technicaljournal@ambujacement.com.

Only original contributions to the construction field are accepted for publication; work should incorporate substantial information not previously published.

Elements of a Paper

The basic elements of a paper or brief are listed below in the order in which they should appear:

1. title
2. author names and affiliations
3. abstract
4. body of paper
5. acknowledgments
6. references
7. figures and tables
8. Style Guide

Title

The title of the paper should be concise and definitive. Author Names and Affiliations Author name should consist of first name (or initial), middle initial, and last name. The author affiliation should consist of the following, as applicable, in the order noted:

- o university or company (with department name or company division)
- o mailing address
- o city, state, zip code
- o country name
- o e-mail (university or company email addresses should be used whenever possible)

Abstract

An abstract (500 words maximum) should open the paper or brief. The purpose of the abstract is to give a clear indication of the objective, scope, and results so that readers may determine whether the full text will be of particular interest to them.

Body

The text should be organized into logical parts or sections. The purpose of the paper should be stated at the beginning, followed by a description of the work, the means of solution, and any other information necessary to properly qualify the results presented and the conclusions. The results should be presented in an orderly form, followed by the author's conclusions.

Headings

Headings and subheadings should appear throughout the work to divide the subject matter into logical parts and to emphasize the major elements and considerations. Parts or sections may be numbered, if desired, but paragraphs should not be numbered.

References cited

All references cited in the text, figures, or tables must be included in a list of references.

Tables & Figures

All tables & figures should be numbered consecutively and have a caption consisting of the table & figure number and a brief title. Table & figure references should be included within the text in numerical order according to their order of appearance and should be inserted as part of the text.

Style Guide

Manuscripts should be double-spaced and left-justified throughout; text lines should be numbered consecutively. Submit the file in its native word-processing format (.doc or docx is best).length of the paper is restricted to maximum 8 pages (A4 size) with the use of a 'standard' font, preferably 12-point Times New Roman.

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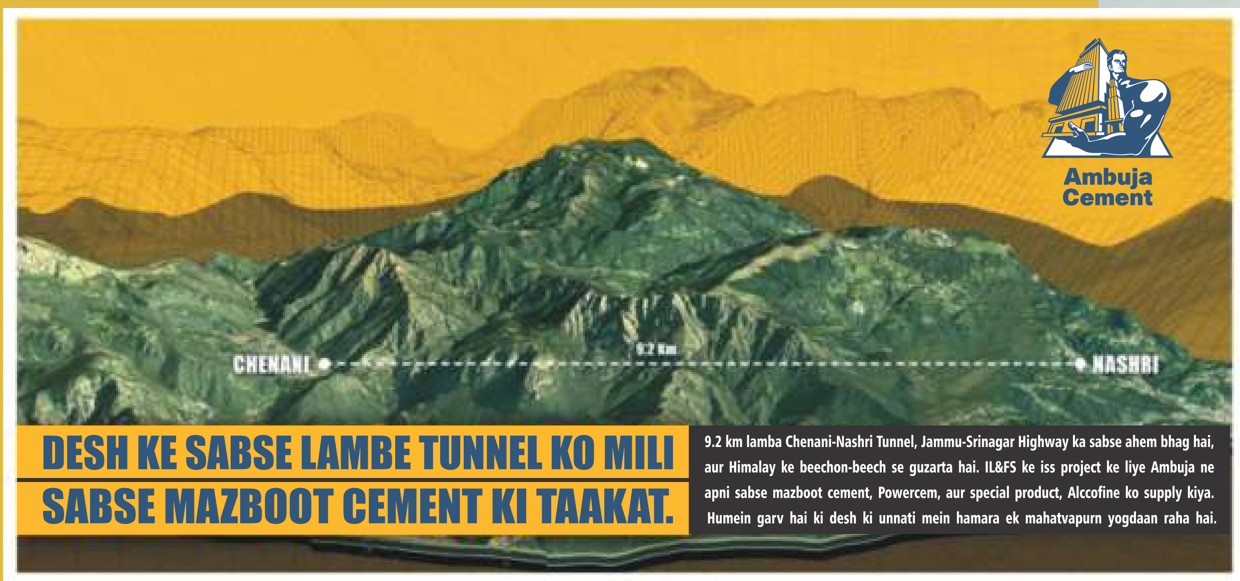

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