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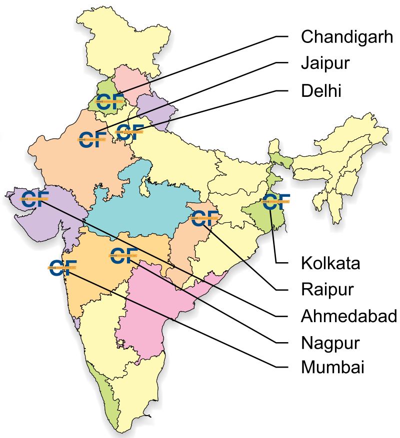

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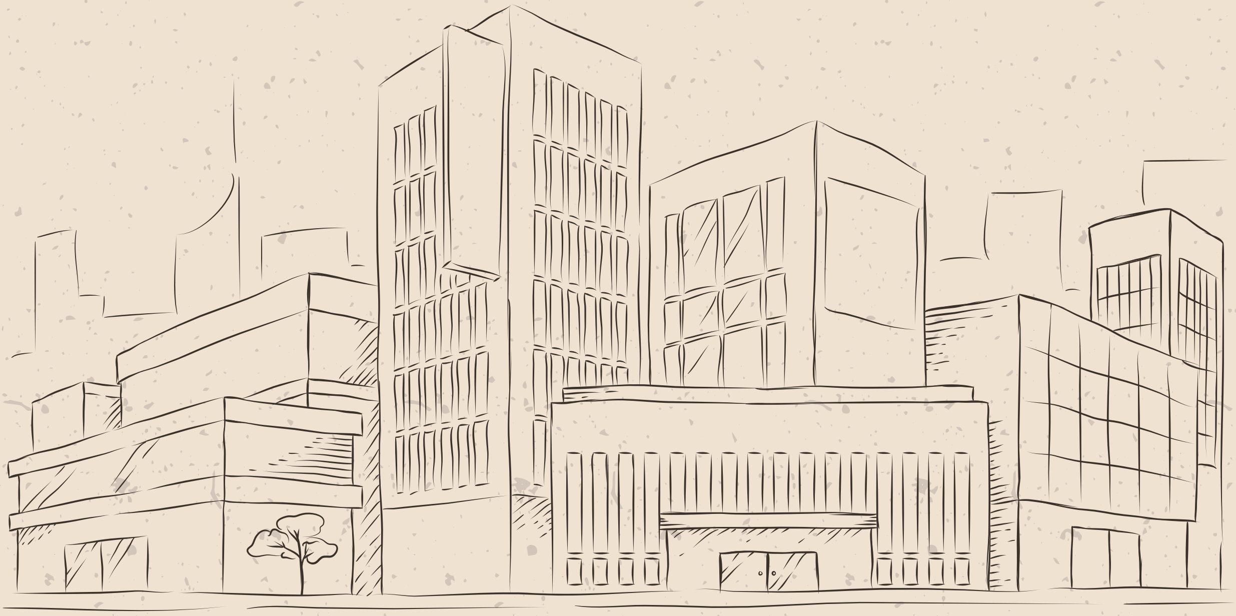

EDITORIAL

Construction industry plays a major role in the economic growth of a nation and occupies a pivotal position in the development plans. India's construction industry has a market size worth about Rs. 2,48,000 crores. It is the second largest contributor to the GDP with 308 billion annually (a share of @ 20%) after the agricultural sector. This statistics clearly indicates that Indian construction industry is going towards northern trajectory.

At the same time, cement, concrete and construction practices are undergoing a big sea change in terms of innovations, in terms of differentiation as well as applications.

Newer products with cement and concrete are being discovered on a regular basis, which help us to undertake building structures, which had never been even thought about earlier.

Usages of, otherwise natural pollutants, like Fly ash & Slag, mixed in right proportions with cement, have been found to generally improve the quality of building material & give better finish too.

Getting to understand them, that too in one place, is the endeavour of this Ambuja Technical Journal and we are happy to bring forward another issue of the same.

We have tried to compile some of the wonderful innovations / discoveries in cement & concrete, which we are sure would be a good read for you all & would go a long way in your endeavours to build beautiful, cost effective designs & sustainable structures.

Happy reading to all!!!!

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HPC to UHPC - Are We Ready for The Transition?

A. K. Mullick

The concept of High Performance Concrete (HPC) as something different from the ordinary, run-of-the mill concrete was evolved nearly five decades back. HPC was designed to meet special requirements of strength, durability and fluidity of concrete for individual projects, by choice of appropriate materials, workmanship and quality control. In India, high performance concrete has been widely adopted in Nuclear power generation projects, infrastructure and projects in water resources sector. Meanwhile, development of concrete with greater and higher characteristics, called 'Ultra High Performance Concrete' (UHPC) has been pursued in many countries. This paper summarises the trend and challenges before widespread application of UHPC in India for structural engineering projects becomes possible.

Keywords: *Concrete; high strength; durability; ductility; fiber reinforcement; strain-hardening; new constructions; strengthening and repairs.*

High Performance Concrete

Advent of superplasticisers and silica fume are among the foremost developments in concrete technology in the last few decades; which led to high strength and high performance concrete. Superplasticisers allowed the workability of concrete to increase greatly, or to lower the water/cement ratio, resulting in lower capillary porosity and high compressive strength. Addition of silica fume aided high strength by pozzolanic reaction and denser packing of solid particles by fine powder effect. This resulted in higher compressive strength and enhanced durability.

High performance concrete is defined as 'Concrete, which meets special performance requirements that cannot be always achieved routinely by using only conventional materials and normal mixing, placing and curing practices'. The requirements may involve high strength; greater durability and increased service life in severe environments; high ductility, toughness and blast resistance etc. [1,2].

Another requirement can be very high workability without segregation; this is the main characteristic of self-compacting concrete (SCC).

Basic considerations

The basic considerations of high performance are the relationships linking water-cement ratio to strength and durability of concrete. The requirements of high strength and low permeability (high durability) are achieved by [3].

- Low water-cement ratio for high strength (Figure 1),
- Low water-cement ratio for low permeability (Figure 2),
- Pore blocking by fine powders
- Part replacement of cement by silica fume, fly ash or slag to reduce cement content
- Increased fine powder and low water content require use of superplasticisers.

Another aspect requiring attention is the brittle nature of concrete. Concrete is a quasi-brittle material, prone to cracking. The brittleness increases with high strength (Figure 3). Another related development, therefore, is the use of fibre reinforcement, to improve ductility, crack resistance and toughness.

Necessary ingredients

With the above information, it is easy to list the necessary ingredients of high performance concrete. Cement, aggregates and water are the usual ingredients of concrete; additionally, for high performance concrete, the following are required [3];

- Silica Fume,
- Superplasticisers,
- Fly ash, Granulated Slag – optional,
- Viscosity modifying agents (VMA) for very high workability concrete, self - compacting concrete (SCC).
- Fiber reinforcement for ductility, toughness, abrasion resistance.

Typical applications in India

High strength and high performance concretes have been widely used in India during the last three decades for construction of nuclear power projects, long span bridges, high-rise buildings and water resources projects. As such only a few illustrative applications are mentioned below.

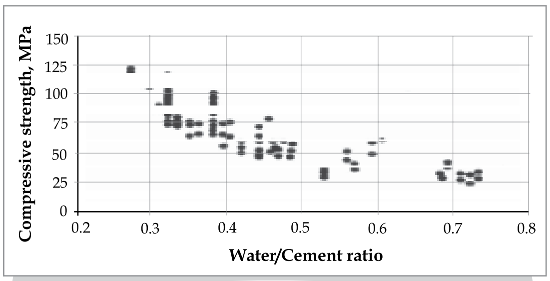

Figure 1. Relationship between water cement ratio and compressive strength (2)

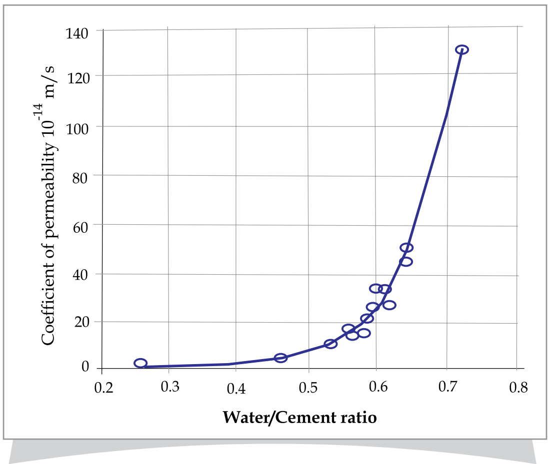

Figure 2. Relationships between water cement ratio and permeability of concrete (2)

High strength concrete is used where strength is the basic consideration, e.g. in buildings, industrial structures. It is noteworthy that IS 456 (draft revision) defines 'High Strength Concrete' from Grades M65 to M100, but does not mention high performance concrete. On the other hand, where durability is added consideration, e.g. in river bridges, high performance concrete is used. IRC Concrete Bridge Code IRC 112:2011 defines 'High Performance Concrete' from Grades M30 to M90. It should be kept in mind that high performance concrete is not always the same thing as high strength concrete.

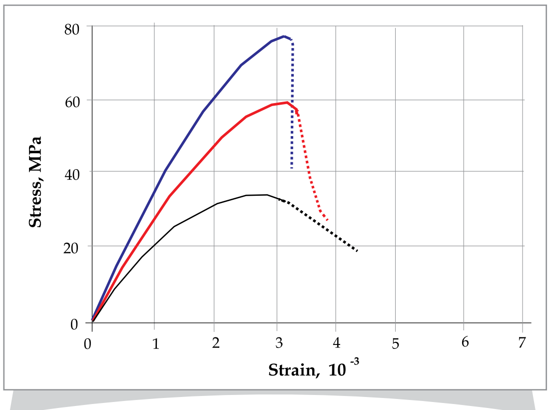

Figure 3. High strength concrete is more brittle and ultimate strain is lower (2)

Target compressive strength of concrete at 28 days was 83.2 MPa. The mix composition per m3 of concrete was as follows.

- Cement - 500 kg
- Silica Fume - 50 kg
- Fine aggregate - 682 kg
- Coarse aggregate - 1156 kg
- Water - 148 litres (w/b ratio = 0.269)
- Superplasticisers - 8.25 litres Properties of concrete achieved in the field were:
- Slump- 130 to 180 mm at RMC plant,
- 80 to 120 mm at placement, after 150 minutes,
- Field strength obtained was 79.6 MPa at 28 days (average) and 94 MPa at 365 days.
- CoV - 2.64%.

The low variability was testimony to strict quality control.

Coming to high performance concrete, domes of Reactor buildings in nuclear power projects at Kaiga, Tarapur and RAPP (Figure 5) were among the first to use high performance concrete [5]. The performance characteristics required were; moderate compressive and high tensile strength; very high durability; low creep and shrinkage; low permeability and good workability. Relatively crack-free performance was required to prevent leakage of radioactivity.

Typical mix proportions (per m3 of concrete) are given in Table 1.

Average 28–day compressive strength was 77 MPa, and CoV was 5%. The cement content was reduced subsequently, as experience was gained.

This project was among the earliest to use ternary blend for binder system (OPC + fly ash + silica fume), now becoming common. This practice of ternary cement blends allows optimum packing of fine materials; a trend which is extended to all solid materials including aggregates in further developments of high performance concrete [6]. It is to be noted that M60 Grade concrete was achieved with 320 kg cement per m3.

In the Waterways Sector, high performance concrete is used for locations subjected to abrasion and impact, e.g. intake; overflow sections, sluices and stilling basins in spillways. M60 concrete is routinely specified for such applications [6]. Another area of application is for immediate and permanent roof support for underground caverns like Powerhouse, Transformer Hall, Desilting chambers and Sedimentation chambers, or for lining of tunnels, where fiber-reinforced shotcrete is used

Self-compacting Concrete

Another type of high performance concrete is Self Compacting Concrete (SCC). Self-Compacting Concrete is a concrete that fills uniformly and completely every corner of formwork by its own weight and fluidity without application of any vibration, without segregation, whilst maintaining homogeneity. It is suitable in situations where:

- reinforcement is very congested,
- access to allow vibration is not available,
- Complicated geometry of the formwork,
- pouring is possible only from a single point,
- speedy placement is required,

Table 1. Mix proportions for HPC in nuclear power projects [5]

Ingredients, kg	Kaiga (IC dome)	RAPP (IC dome)	TAPP (IC structure)
Cement	475	475	475
Silica fume	35.6	36	35.6
Water/Ice	163	152	152
Coarse aggregate.	1092	1047	1133
Fine aggregate.	695	730	721
Super plasticiser, lt.	8.4	9.63	9.53
Water/cement	0.343	0.32	0.32
Water/binder	0.32	0.3	0.3

It has also the other advantages of no noise due to vibration and no requirement of finishing.

Because of ease of placing, SCC is now widely used in many constructions in India. Its applications started with concrete of moderate strength grades (M35 or so), where congestion of reinforcement or difficulty in placing were the primary reasons. Its application to high strength concrete (M60 Grade) was extended to bridge piers in Signature Bridge in Delhi [6], and later on to many high-rise buildings, where M80 or M90 grade concrete is being used [7].

Table 2. Mix proportions for M60 grade concrete for pile caps, Bandra-Worli project

Constituents	Quantity, per m^3 of concrete
Cement	320
Fly ash	106
Silica fume	42.5
Water	78
Fine aggregate	890
Coarse aggregate	1080
Super plasticiser	3.4 % bwoc

In absence of any Code for mix design, comprehensive guidelines of EFNARC are widely used [8]. It also prescribes necessary tests for fluidity, passing ability and cohesiveness of concrete and suggests appropriate values of test results for different placing conditions.

Further Developments – UHPC

With appropriate mix design, high strength and high performance concretes of compressive strength approaching 100 MPa at 28 days became common, including in India. Simultaneously, development of very high strength concrete following 'Reactive powder concrete (RPC), Macro defect free cement (MDF) or Dense silica particle cement (DSP) routes were pursued. New generations of high efficiency superplasticisers rendered high fluidity; and fibre reinforcement was used for ductility and toughness. These led to the recent trend in many countries for developing ultra high performance concrete (UHPC) and their industrial applications. Compared to common strength level in HPC of around 60 - 100 MPa, the ultra high performance concrete have strength levels of up to 200 MPa or more. A common classification on the basis of compressive strength is given below;

- High strength concrete (HSC) - 50 to 100 MPa,
- Very high strength concrete (VHSC) – 100 – 150 MPa,
- Ultra high strength concrete (UHSC) – 150 – 200 MPa, and

- Super high strength concrete (SHPC) - 200 - 250 MPa.

Table 3. Typical mix composition of Formulation 1 [10]

Material	Amount, kg/m^3	% by weight
OPC	712	28.5
Fine sand	1020	40.8
Silica fume	231	9.3
Ground quartz	211	8.4
HRWR	30.7	1.2
Accelerator	30	1.2
Steel fibers	156	6.2
Water	109	4.4

As mentioned above, these are achieved with use of improved materials, very high amount of cement and silica fume (called 'reactive powders'), low water/binder ratio of the order of 0.11 – 0.22 made possible by use of higher dosage of high efficiency superplasticisers, and aggregates of small sizes (<500 μ). Addition of fibers results in high flexural strength and improved ductility. Conventional sized coarse and fine aggregates are omitted. Some of the formulations are commercially available in well-known trade names (UHPC Formulation 1 or 2).

Reactive powder concrete (RPC)

High cement content and silica fume, very low water binder ratio are adopted; and high volume of steel fibers are added to render ductility. RPC does not contain coarse aggregate and maximum size of fine aggregate is 0.4 – 0.6 mm (400 to 600 μ). Compressive strengths of 170 – 230 MPa or higher have generally been obtained. A typical mix composition of Formulation 1 is given in Table 3.

Special industrial concrete (Formulation 2)

Mix proportions are similar to Formulation 1 above, except fine aggregate of size up to 6 mm are used. Typical strength levels are 150 – 175 MPa.

ACI Committee 239 has given definition for Ultra High Performance Concrete (UHPC) as 'Concrete that has minimum specified compressive strength of 150 MPa with specified durability, tensile ductility and toughness requirements; fibers are generally included to achieve specified requirements' [9].

Federal Highway Administration (FHWA) of USA defines UHPC class materials as 'cementitious-based composite materials with discontinuous fiber reinforcement that exhibit compressive strength above 150 MPa, pre- and post- cracking tensile strength above 5 MPa and enhanced durability via a discontinuous pore structure' [10].

Early applications

A recent (October 2015) Symposium on 'Ultra High Performance Concrete' held in Kolkata contains state-of–the-art information on development, applications and challenges on use of UHPC [11]. Much of the information given below is gathered from the above publication. It lists pioneering applications of UHPC as:

- 130 MPa UHPC for an 88 story building in Chicago (1987),
- 300 MPa UHPC used for 60m long Sherbrook bridge in Canada (1997), and
- 200 MPa UHPC used for 120 m long pedestrian bridge in Seoul, South Korea (2002).

Sherbrooke Bridge (Figure 6) has 60 m clear span, 3.3 m wide. It was constructed with six precast UHPC elements. The precast elements were 3-dimensional space truss, which were post-tensioned at site. 300 MPa Formulation 1 concrete was used. It is used as a footbridge [12].

Bridge of Peace in Seoul, South Korea (Figure 7) has 120 m span, The structure consists of six precast units made with 200 MPa Formulation 1 concrete. In longitudinal directions, the segments are post-tensioned by six tendons. In transverse direction, single strands are used along with small, specially produced anchors [13].

Opportunities and challenges on large scale application

Ultra high performance concrete not only offers extremely high compressive strength, but outstanding durability. Extremely high compressive strength of concrete will allow high degree of precompression and high level of tensile stresses can be compensated [10, 11]. Addition of fibers provides major enhancement of ductility and tensile capacity. The most notable characteristic is extremely dense microstructure of the matrix due to the high amount of fines with an optimum particle packing density and low water/binder ratio. Among important material properties, it is recognised that creep and shrinkage are lower than normal concrete, and sufficient fatigue resistance [10]. Much of the total shrinkage is autogenous shrinkage. The losses in prestress due to creep and shrinkage are expected to be lower than normal concrete. Consequently, long span structures or very high buildings with reinforced and prestressed concrete are potential areas of application.

However, wide scale application has been restricted due to the fact that UHPC-specific structural design rules are not available [9, 14]. Framing of design rules and testing standards have been identified as a major task for ASTM and ACI [9]. Similarly, Task Group 8.6 of FIP is also charged with developing recommendations tailored to the design of UHPC structures. This is, notwithstanding, that some guidelines/interim recommendations are available from Australia, Japan Society of Civil Engineers (JSCE) and SETRA-AFGC in France [10].

All the earlier applications in Europe and North America were designed with conservative approaches, fully prototyped and load tested to failure, including fatigue testing to one million cycles. US FHWA has been co-ordinating development of UHPC for Highway program since 2001. In 2006, it introduced 34 m long UHPC I-girders with a conventional cast-in place RCC deck slab. Use of three UHPC I-girders without any stirrups for shear reinforcing was a significant aspect. During the same period, 'optimised' precast bridge profile, called 'Pi (π) –Girder' was prototyped and used in bridges (Figure 8). In the early implementation of such break-through technology, risks of owner, designer, concrete suppliers and contractors added to the costs [14]. References 10 and 11 give a good insight into the current research activities on material- and structural design aspects being carried out in Europe, USA and some Asian countries like South Korea and China. An indicative list is given in Table 4.

Ultra High Performance Fiber-Reinforced Concrete (UHPFRC)

Meanwhile, more applications are reported for repair and capacity enhancement of existing concrete structures, which require high strength, improved durability and multiple fine cracking phenomena. The latter property is owing to 'strain-hardening' nature of the composite. Such a composite will have very high tensile strain capacity; about 4 percent i.e. 400 times that in normal concrete. The concept of strain-hardening is explained in Figure 9 [15]. In conventional FRC, peak stress will be followed by a falling softening branch, with not much increase in tensile strain and opening of large crack (Figure 9 (a)). On the other hand, the stress-strain curve of a strain-hardening composite starts with a steep initial ascending portion up to first structural cracking (Figure 9 (b) - part I), followed by a strain-hardening branch where multiple micro cracks develop (part II) [15]. The peak point at the end of strain-hardening branch, B in Figure 9(b) corresponds to the maximum post-cracking stress and strain.

At the peak point, one crack becomes critical; onset of crack localization takes place, and decrease in the resistance (Figure 9 (b) - part III). Multiple crack formation, of 50 μ to 70 μ width,

rather than a single crack, is important for strain-hardening response.

Applications in repair and strengthening

Pioneering applications of UHPC for strengthening and repair of structural members are reported in Reference 16. Typical examples include;

- Widening of existing bridge (Figure 10).
- UHPFRC protection to a crash barrier wall.
- Rehabilitation of bridge pier using precast UHPFRC shell elements (Figure 11), and
- Strengthening an industrial floor.

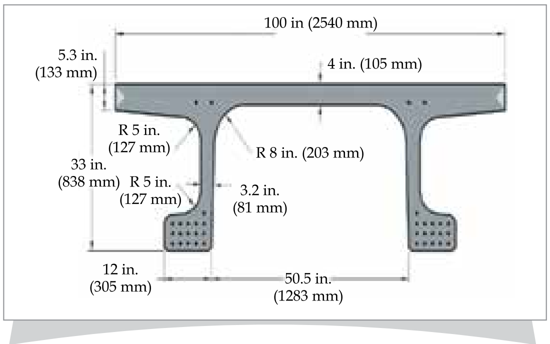

Figure 8. Cross section of π - shaped girder [10]

Typical composition of UHPC in such applications will be as given in Table 5 [11,16].

Fine powders are batched pre-mixed, which are then mixed with the other ingredients in a high shear mixer. The mixing can be at the site or transported after mixing in a central plant [14]. The workability is high; around 200 mm slump. After 24 hour curing at room temperature, the mix may have to be steam-cured at 90oC for 48 to 72 hours. In such cases, precast elements are used. The design compressive strength is 180 MPa and design tensile strength 13.0 MPa.

Table 4. Current topics of research on UHPC (indicative list)

Area	Sr. no.	Topic
Material aspects	1	Optimisation of mixtures
	2	Nanotechnology for UHPC
	3	Distribution and orientation of fibers
	4	Fatigue and fire resistance, impact
	5	Material testing for UHPC, including NDT
Structural behaviour	1	Flexural analysis - stress block, rigid - plastic relationship for tension
	2	Combined reinforcement of fibers and rebars
	3	Design under bending, shear, torsion Under SLS and ULS
	4	Application of strut and tie models
	5	Bond stresses, transmission length. anchorages
	6	Connection techniques, connectors, structural gluing
	7	Elimination of stirrups for shear forces by fibers
	8	Influence of web openings
	9	Strengthening with UHPC; interface strength with
	10	For prestressed concrete, stress limit and prestress losses for UHPC

Indian effort – jointless bridge decks with ECC

Use of strain-hardening, ductile concrete of normal strength grades (M40 or M50) have been proposed for joint less bridge decks in NHAI project [17]. Because of high tensile strain capacity and controlled crack behaviour, expansion joints are proposed to be eliminated. This is in line with what has been adopted in USA and also called 'Engineered Cementitious Composites' (ECC). The concept is explained in Figure 12.

Table 5. Typical composition of UHPC for repair applications

Materials	Relative mass
Cement 1.0	1.0
Silica fume 0.25	0.25
Fine sand 1.1	1.1
Quartz powder 0.3	0.3
Superplasticiser 0.018	0.018
Water/binder 0.2	0.2
Steel fiber (Vf, %) 1.5 – 2.0	1.5 - 2.0

In order to have continuous deck slabs without expansion joints, ideally concrete should be one which does not crack. This is a hypothetical solution, because each concrete will exhibit cracking at some level of stress. What can be attempted is to have concrete exhibiting limited cracking under service conditions, which does not endanger durability. Another distinct approach is to use high performance fiber–reinforced cementitious composites (HPFRCC) designed to resist large tensile and shear forces, but having compressive strength comparable to usual structural concrete. These are suitable for structural applications that require large ductility. Unlike ultra-high performance concrete (UHPC) described above, HPFRCC has mix proportions not much different from usual structural concrete, including use of coarse aggregate. The primary requirement of the composite for applications in jointless link slab is to strain-harden under uniaxial tension, while forming large number of micro cracks up to an ultimate strain capacity. Required properties are given in Table 6.

Flexural strength	16 MPa
Tensile strength	6 MPa
Compressive strength	60 MPa
Tensile strain capacity	4 %
Modulus of elasticity	18 GPa
Density	2000 kg/m^3

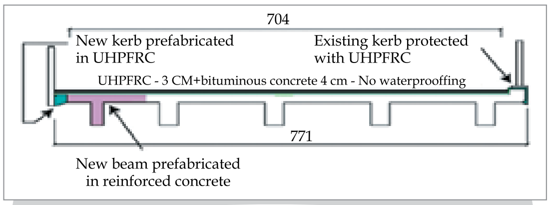

Figure 10. Widening of an existing bridge with UHPFRC

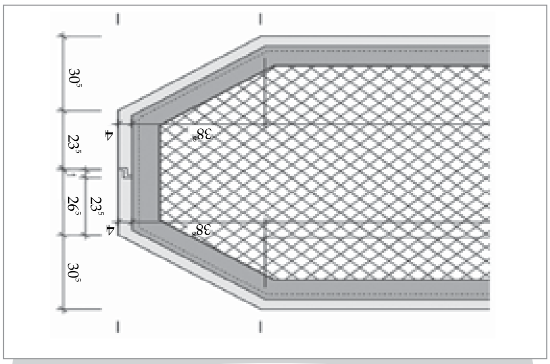

Figure 11. Rehabilitation of bridge pier using precast UHPFRC shell elements.

IIT's and SERC Chennai have reported investigations on high and ultra-high performance fiber-reinforced concretes. In SERC investigations, the 28 – days compressive strength of the composites ranged from 81MPa (high performance concrete) to 188 MPa (Reactive powder concrete). Uses of different types of fibers – both steel and polymer, like PVA or PP, to obtain strain-hardening behaviour have been investigated by different academic institutions. Use of UHPC overlay for repair of damaged RCC beams have been reported from SERC Chennai.

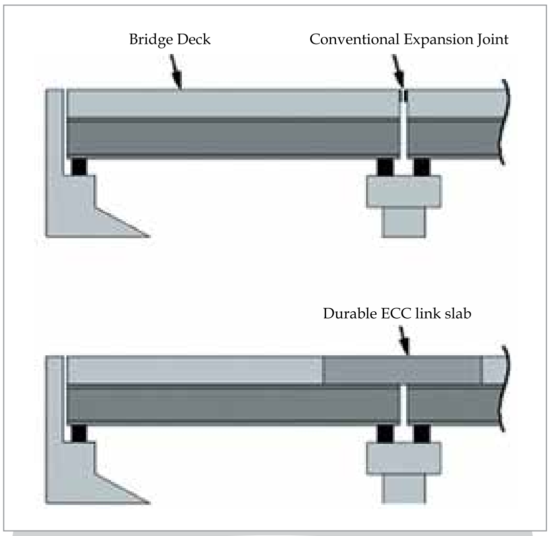

Figure 12. Jointless bridge deck with ECC

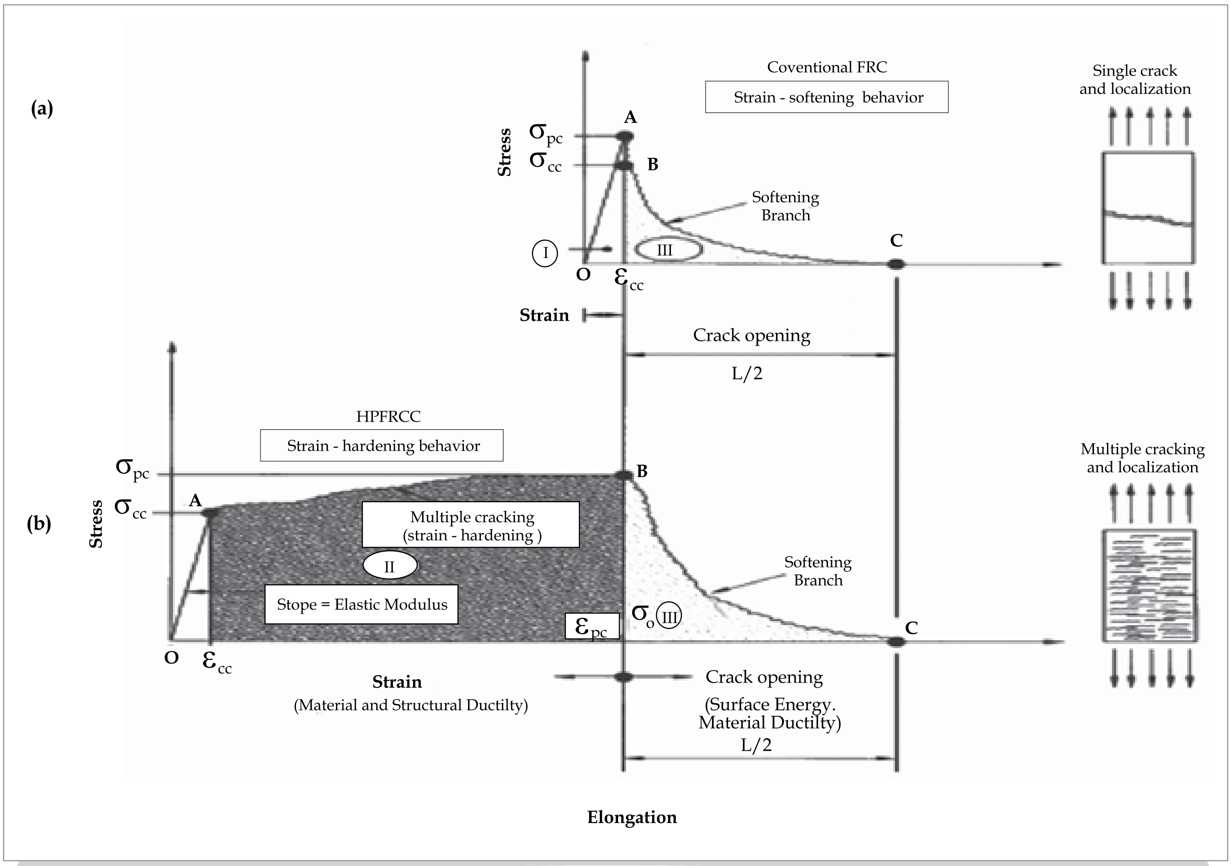

Figure 9. Stress-strain or elongation curve in tension of (a) strain-softening and (b) strain hardening FRC composites [15]

CONCLUSIONS

It is apparent that design and construction of high-rise structures or long span bridges with UHPC will have to wait, till design rules are framed abroad and then in India. Enterprising engineers can opt for innovative designs on the basis of prototype testing, which is permitted in our design Codes. However, use of UHPC for repair, strengthening and retrofitting applications can start straightway.

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Role of GGBS in Producing Durable, Economical and Most Sustainable Concrete

Dr. N V Nayak

Preamble

Many Secondary Cementing Materials (SCMs) like Fly ash, GGBS, Metakaoline, Rice Husk Ash, Silica Fume, Ultrafine Slag and Ultrafine Fly ash are found to be very useful in producing durable, economical concrete. All these products except metakaoline are waste product. A century back, disposal of them was a problem but now they are turned out to be very useful products.

Of these various SCMs, flyash and GGBS are mainly used in production of blended cement concrete. Of these two SCMs, GGBS scores over fly ash in marine conditions, industrial waste disposal area and in resisting sulphate attack. Further, GGBS score extremely well over any other SCMs in producing highly sustainable concrete. However, cost wise fly ash is much cheaper than GGBS. Also it is easily available practically all over India.

Introduction

Ground granulated blast furnace (GGBS) is a by-product from iron manufacturing industry. GGBS is commercially produced and used in concrete in Europe over 150 years. In India, it is in use for over 50 years and its use is increasing year by year.

India produces only around 5 million tons of GGBS, practically all of which is consumed locally. If all the slag from iron industries is converted to GGBS, we can produce almost 36 Mt (million tons) of GGBS annually.

Main Factors contributing to Production of Durable, Sustainable and Economical Concrete

The following two main factors mainly contribute in producing durable, sustainable and economical concrete are

Low water binder ratio (w/b)
Use of SCMs

For durability it is very desirable that we use low w/b ratio, generally between 0.3 to 0.35. Lower the w/b ratio, higher is the strength, higher is the impermeability and hence higher is the durability. The other factor, contributing to durability, sustainability and economy of concrete is the use of secondary cementing materials (SCMs). Mainly used SCMs are fly ash, GGBS, metakaoline, rice husk ash and silica fume. All these products except metakaoline are from waste products.

When we use SCMs, we use waste product, we minimize depletion of natural resource i.e. lime stone and also make concrete more durable, more sustainable and more economical.

Durable Concrete

If the concrete has to be durable, it should be able to withstand various environmental hazards. For example, it has to resist

1. Chloride Corrosion
2. Carbonation
3. Alkali Silica Reaction
4. Sulphate Attack
5. Industrial Waste Pollution

It is observed that in marine conditions, GGBS is highly effective. Further it is very desirable that one should have high permissible percentage of GGBS. The minimum high permissible percentage as per various national standards is 70% (IS 456), maximum permissible high percentage is 95% (CEM III/C, BSEN 197, 2000). Author strongly recommends use of GGBS in the range of 70% to 85%, if that is only the SCM used in concrete.

Fly ash is also good in resisting chloride corrosion but it is not as effective as GGBS. Further permissible high percentage of replacement is between 35% (IS 456) and 55% (BSEN 450, 2012) as per the various national standards.

Of all the SCMs, the permissible replacement of cement by GGBS is highest. Hence, highest sustainability of concrete is achieved when we use GGBS.

For resistance against carbonation, both fly ash and GGBS are found to be practically equally effective. Fly ash is cheaper than GGBS but higher percentage of replacement is permitted by national standards with GGBS.

For resisting against alkali silica reaction, one should use highest permissible percentage of SCMs. As per IS 456, we should then therefore use 70% replacement with GGBS.

For resisting sulphate attack both GGBS and fly ash are found to be effective. However, GGBS scores over fly ash. Silica fume and metakaoline are not to be preferred.

The limited study conducted by Mr. Ganpule (2010), has indicated that the only effective SCM against industrial waste is GGBS. Further, it is better to use highest permissible replacement by GGBS as permitted by the national standards to get better resistance. The above is based on limited study done in industrial areas in and around Mumbai. To be applicable to wide variety of Industrial areas, further studies need to be conducted in different industrial zones with different varieties of industrial disposal, etc.

Blending at Site or at Manufacturing Facilities

Blended cement can be produced at cement plant or blending can be done at site and RMC plants. There are many advantages of blending at site/RMC plants. When blending is done at cement plant, PSC (Portland Slag Cement) contains GGBS only around 50%. But when we blend at site we can use GGBS to the highest permissible limit of 70% or more permissible replacement. Similarly for PPC (Portland Pozzonlana Cement), manufacturer replace only around 30% by fly ash whereas at site, we can use higher percentage say 35% and even higher permissible percentage. Higher percentages means more durable, sustainable and economical concrete. Further unit price range of OPC, PSC, PPC manufactured at cement plants, range over a small scale. In other word, benefit of using SCM in manufacturing cement at cement plant is taken by manufacturer. When site blending is done benefit goes to contractors/ clients. Of course when blending is done at site/ RMC, proper quality control is needed.

GGBS Vs Fly Ash : Merits and Demerits

Fly ash and GGBS are most widely used SCMs in India. Hence, a comparison is made between GGBS and fly ash as indicated in Table 6.1.

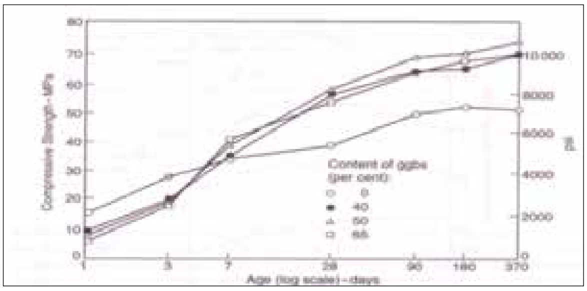

Figure 1. Development of compressive strength of concrete (measured on cubes) moist cured at room temperature for various contents of ggbs by mass of total cementitious material [13.132] (Copyright ASTM - reproduced with permission)

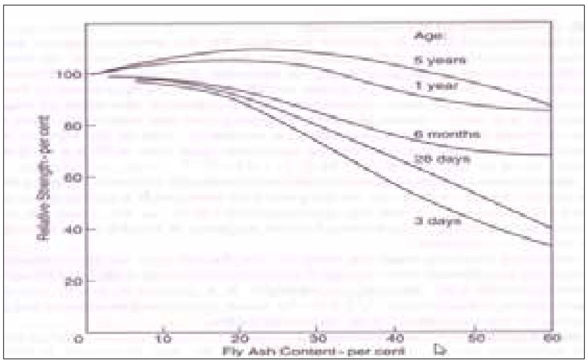

Figure 2. Influence of content of fly ash in the cementitious material (by mass) on strength of hardened cement paste[13.19]

Conclusions

From durability, sustainability and economic consideration use blended cement concrete and not OPC concrete. Further, use maximum highest permissible replacement with SCM and prefer site/RMC blending.

	GGBS	FLY ASH
Permissible percentage Replacement	Higher (70% - 95%)*(+)	Lower (35% to 55%) (-)
Quality of Product	Very Stringent & very consistent (+)	Not stringent and not very consistent (-)
Cost of Product	Generally costly (40-50% of cost of cement) (-) (But Concrete may workout cheaper with higher percentage of GGBS) (+)	Generally cheap (≈ 20% of cost of cement) (+)
Hydration	Hydraulic (+)	Non-hydraulic (-)
Mass Concrete – Concrete Temperature	Lower mainly because of higher permissible replacement (+)	Relatively higher because of lower permissible replacement (-)
Production Facilities/Availability	South India, Western India. Hence, more costly in Northern India (-)	Practically all over the country. Hence cheaper (+)
Long term strength over 28 days strength	Much higher than OPC (≈ 35 to 40%) with 70 to 85% GGBS) (+) (Fig.6.1)	Lower than high % GGBS but more than OPC (≈ 25% to 30% with 35% to 55% replacement) (-) (Fig.6.2)
Creep – Initial and Total	Far less with permissible high percentage of GGBS and small percentage of UFS (Alcofine) (3% - 6%) (+)	More than GGBS with high permissible percentage of fly ash and small percentage of UFFA (6 to 20%)
Segregation and bleeding	Lower chances than OPC (+)	Lower chances than OPC (+)

Blending with GGBS is preferable in marine environment, industrially polluted areas and sulphate bearing strata. Further, blending with GGBS, with highest permissible replacement as per relevant national standards give highest degree of sustainable concrete.

In India, the unit price of GGBS is roughly 40% of OPC whereas that of fly ash is roughly 20% of OPC. Hence, from economical considerations we can use GGBS and fly ash combinedly.

Finally the author would recommend replacement of 70% to 85% with GGBS alone or combination of GGBS and fly ash.

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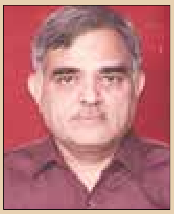

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Strengthening Of Bridge Structures Using CFRP Systems

Manish Mokal & Pranal Rokade

Abstract

Bridge structures deteriorate due to various reasons over time. In many situations, merely repairing the cracks and spalls are not sufficient and there is a need to strengthen the structure in order that it serves its desired purpose. There are various conventional practices for strengthening which have been extensively used but they have many shortcomings. Off late a new technique for strengthening of concrete structure with the help of fibre wrapping has come up. In this paper, causes for strengthening of bridge structures, existing practices along with its merits and demerits and strengthening with the help of CFRP has been discussed.

Keywords: Carbon fibre reinforced plastic, strengthening, bridge, beams, columns, slabs

Introduction

Concrete is one of the most versatile construction materials and majority of the bridges build across the world are concrete structure. Concrete over a period of time deteriorates for various reasons and requires maintenance, rehabilitation/ strengthening work in order to continue its serviceability.

There are various strengthening / rehabilitation procedures. Strengthening with the help of carbon fibre reinforced plastic (CFRP) is one of them. This is a new technique having tremendous potential. In this paper, why strengthening is required, existing procedures of strengthening and strengthening procedure with the help of CFRP have been discussed.

Requirement Of Strengthening Of Concrete Bridges:

Strengthening of a concrete bridge structure may be required on account of one or combination of the following:

- Deterioration of structure due to environmental effect
- Revision in loading standard

Deterioration of Structure Due To Environmental Effect -

Concrete is heterogeneous as well as porous material. It allows ingress of air and moisture in it. Ingress of moisture, air allows chemicals like carbon dioxide, chlorides and sulphates to enter into concrete. They deteriorate concrete causing the concrete to crack. These cracks accelerate further deterioration and may cause the structure to lose its structural integrity and strength.

Revision In Loading

The loading conditions may change over time due to change in traffic condition, axle loading or due to change in the loads considered in the relevant codes. The bridges built earlier are now being subjected to higher loads due to increase in axle loads. This increase in loads leads to strength deficiency in the structure and it needs to be furthered strengthened in order to cater to its serviceability.

Traditional Strengthening Procedures:

Traditionally the strengthening of structures has been done by one or more of the following methods:

- Increasing the section of the member by jacketing
- Providing steel plates on the face of the member
- External prestressing

The above methods have been successfully implemented in many projects across the globe. But there are certain demerits to the above methods:

- Strengthening for vertical portion of structure is possible like columns, piers etc. But, horizontal portion of the structure like girders and deck slab, the same is either not possible or very difficult
- Weight of the structure increases. So the structure needs to be analyzed for the increase in dead load as well as the effect in seismic condition
- In case of large span girders, it becomes difficult to handle the steel plate due to its heavy weight
- In case of joining of plate is required due to longer span, difficulty is being faced in providing butt-welded joint
- Corrosion of externally provided steel plate is a major concern
- Corrosion of prestressing strands.

Carbon Fibre Reinforced Plastic

Many new raw material and techniques are being developed for strengthening of structures. Carbon fibre is one of the material which is used in combination with other materials to form a composite. The properties of carbon fibres such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion makes them one of the most versatile material for strengthening.

Each carbon fibre thread is a bundle of many thousand carbon filaments. A single such filament is a thin tube of 5-8 micrometer and consists of pure carbon. Construction composites that are most commonly reinforced with carbon fibres are called as carbon fibre reinforced plastic. To make a carbon fibre sheet, carbon fibre fabric is saturated with epoxy resins and heated at high temperature. The polymer used in CFRP is most often epoxy, but other polymers, such as polyester, vinyl ester or nylon are sometimes used. General configuration of CFRP is shown in Figure 1. Commercially, CFRP is available as fabric as well as sheet or plates.

Properties of CFRP depend upon the layouts of carbon fibres and the proportion of carbon fibres relative to the polymer. CFRP materials are distinguished by their extremely high strength, rigidity, durability, and high resistance to corrosion, low density, excellent damping properties, and a high resistance to impacts. The main disadvantage of carbon fibres is their catastrophic mode of failure since the carbon fibres are brittle in nature.

Applications For CFRP

The application fields of CFRP include bridges, buildings, tunnels, chimneys, box culverts, etc. the bridge piers, girders, deck slabs and building beams, columns and slabs are the most common to be strengthened. Bridge and chimney have witnessed great success owing to the use of CFRP. Typically a concrete bridge deck has a life of 30-40 years depending upon the durability enhancing measures taken during construction. Old concrete decks constructed with unprotected steel are deteriorating rapidly. Wrapping around bridge sections can restore the load carrying capacity if the member to its original condition. It can also help in enhancing the ductility of the section, greatly increasing the resistance to collapse under earthquake loading. The fibre wrap systems are also being used to repair deteriorated concrete piers, pier caps, concrete arch and damaged beams.

Beam, column and slab strengthening is another very important application of carbon fibre composites. In flexural reinforced concrete members, the addition of carbon fibres improves the modulus of rupture (bending strength).

Methods For Strengthening Various Structural Elements of A Bridge

Depending upon case-to-case and member-to-member, strengthening method differs. Most common methods are described below:

Strengthening Scheme To Enhance the Flexural and Shear Capacity of Girders and Deck Slab

CFRP plates are paste to the bottom (generally the tension face) of the girder or the deck slab. In case of a cantilever section, the plates have to paste on the top. This increases the strength of the beam, deflection capacity and stiffness (load required to make unit deflection).

While strengthening the member, orientation of the fibre is of utmost importance. This is so, because strength of CFRP product is not equal in all directions. In the axial direction of fibre, its strength is the maximum. In flexural members, tension is along the span direction and mainly for that, steel reinforcement is provided. In similar way, while providing the CFRP sheet, the same should be in such a manner that direction of the fibre should be mainly along the span.

As an experiment to assess the enhancement in load carrying capacity of beam with CFRP, beams with and without the wrapping were tested as shown in Figure 2. It was observed that the beams failed at the same deflection, but the load required to reach the deflection in case of the CFRP wrapped beam is much higher than load taken by the beam without any CFRP wrapping. Typical loading versus deflection curve achieved during the experiment is shown in Figure 3. The increase in the load carrying capacity will depend on the amount of CFRP used.

If the member needs strengthening of shear, then CFRP strips and sheets can be paste in "U" shape around the sides and bottom of the beam.

A typical arrangement for strengthening of bridge girder system for flexure and shear is as shown in Figure 4.

Typical arrangement for strengthening of deck slabs is as shown in Figure 5. There may be certain possibilities that in some locations, slabs are bearing concentrated load and maximum moment is localized there. In such cases, provision of CFRP strip should be in the desired zone and not required to be symmetrical in the centre.

STRENGTHENING SCHEME FOR ENHANCING AXIAL CAPACITY OF PIERS

Sometimes, columns, piers and abutments require strengthening to enhance its capacity. Capacity enhancement might be there either on account of flexural or axial or both. In such case, whether it is axial, flexural or combined, FRP sheet needs to be wrapped all around the piers. Schematic diagram of such strengthening is given in Figure 6.

Procedure for Installation of CFRP

Surface Preparation

Before start of the work, it is very much essential to ensure that surface should be dry, clean, free from oil and grease and any type of loose materials.

To ensure little roughness, light sand blasting or grinding can be done followed by proper cleaning of the surface to remove dust particles. Any protrusion should be made good otherwise, it may create void in the nearby area. Crack more than 0.3mm width, if any, needs to be properly epoxy grouted to ensure good quality.

Wet Lay-up Method

After completion of the surface preparation, one coat of epoxy is applied on the surface. Then after, saturated fibre in the appropriate resin is applied on the surface.

Misalignment of the fibre may lead to unsound work. As such, fibre should be properly aligned and slightly stretched to avoid any bend/twist, if any. Number of layers will depend upon the requirement of thickness. After placement of saturated fibre, the same should be properly rolled to ensure its proper compression as well as adhesion to the surface on which the same is applied. Presence of any void will affect the strength.

Utmost care must be taken that the surface should not be wet during application of CFRP sheets. This can eventually cause debonding of the sheet and will lead to loss of load carrying capacity.

Surface Finish

After completion of the fixing the CFRP on the member, a coat of epoxy is applied and fine sand is sprinkled on the epoxy to create a rough surface. This surface can now take any further treatment that is required such as cement plaster, paint, etc.

Design Procedures And Codal Provisions

As the technology is relatively new, most of the works have been carried out based on guidelines and published literature only.

Two major references used as guidelines for design practices are:

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- Concrete Society 2000 – Design guidance for strengthening concrete structure using fibre composite materials. Technical Report No. 55. The Concrete Society, Century House, Telford Avenue, Crowthrone, Berkshire, United Kingdom.

Conclusion

Though CFRP is relatively new technology, the scope for application in construction industry is tremendous. The older bridge structures are requiring strengthening measures either due to deterioration and change in loading.

One of the major restrictions in implementation of this technology is the high cost involved. As the technology is relatively new, most of the works have been carried out based on guidelines and published literature only. At this juncture there is a need for Government - Industry - Institute partnership to exploit the full potential of CFRP so that the technology can be used extensively to breathe new life in the aging bridges in India.

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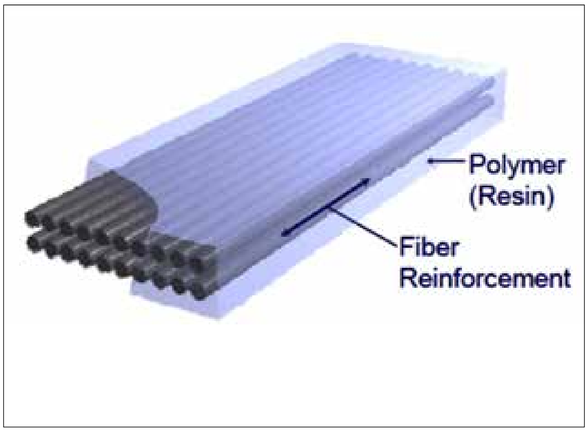

Figure 1. Composition of CFRP

Figure 2. Loading arrangement for testing beam

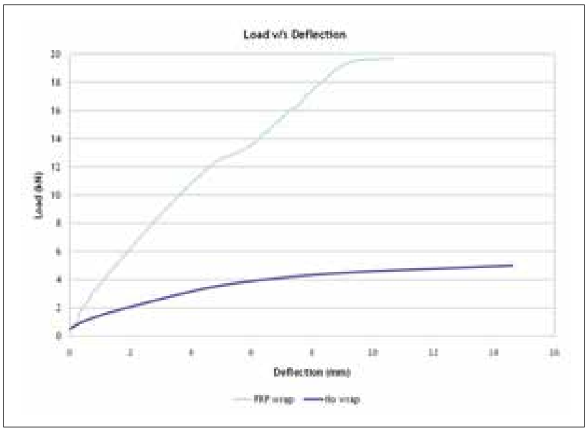

Figure 3. Typical load versus deflection curve

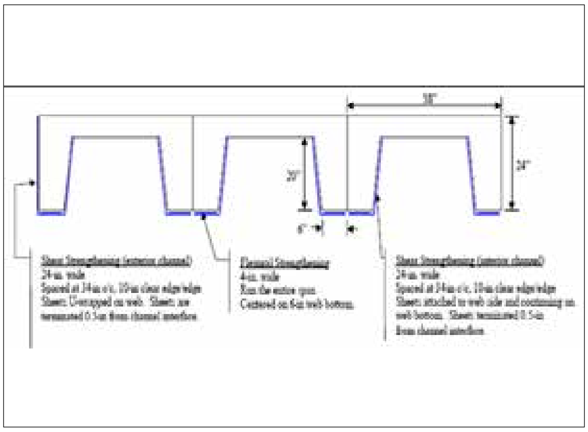

Figure 4. Typical strengthening scheme for flexural members

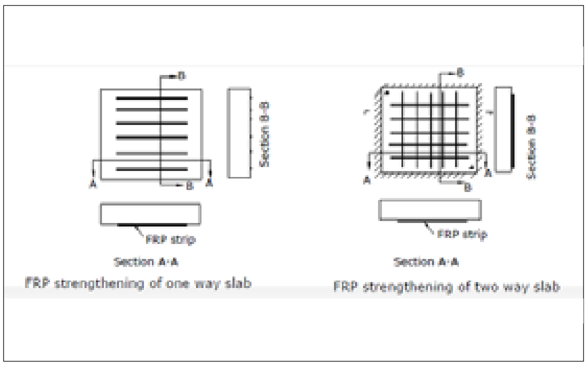

Figure 5. Typical strengthening scheme for slabs

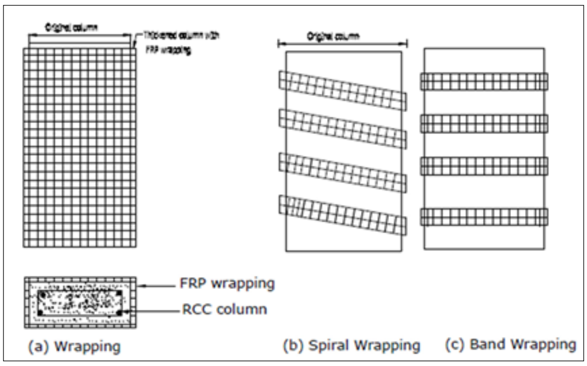

Figure 6. Typical strengthening scheme for axial members

Surface grinding and prepared for fibre wrapping

Surface primer applied on the column

Cutting of fibre sheet

Wrapping with carbon fiber

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Pranal Rokade

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Mr. Pranal Rokade, born in December 1978, holds BE Degree in Civil Engineering from Mumbai University. He is actively involved for the past 17 years in the field of Concrete Technology, repairs and strengthening of various bridge projects.

Structural Audit – Methodology, Guideline, Related Issues & Durability

N. G. Karkhane

Introduction

A building inspection is an inspection performed by a building inspector, a person who is employed by either a city, township or county and is usually certified in one or more disciplines qualifying them to make professional judgment about whether a building meets building code requirements. A building inspector may be certified either as a residential or commercial building inspector, or as a plumbing, electrical or mechanical inspector or other specialty-focused inspector who may inspect structures at different stages of completion.[1] Most building inspectors employed by governments are certified by the State or the International Code Council (ICC). These inspections are done to assure compliance with whatever building, plumbing, electrical, and mechanical or specialty codes, such as swimming pool codes, that are being enforced by the jurisdiction in which they work.

Consulting engineers often carry out structural building inspections for strata properties where there are structural elements of the building found to be unsafe. Whether it is the balconies, balustrades or cracking due to settlement in the walls, consulting engineers provide building inspections of the property and make the appropriate assessment and provide dilapidation reports followed by proposals for remedial action. Other building inspection expertise like facades inspection are often required by certain cities and considered mandatory. These are to be done by engineers and not by contractors. An example of a city that adopted this law is Quebec followed by a fatal incident that occurred due to negligence of the state of a facade. These inspections are often included in a contracted building inspection but might not be carefully analyzed and diagnosed like an engineer would.

Phases of Existence of Building:

- Architectural planning - Architect
- Structural Design - Structural Engineer
- Construction - Contractor
- Maintenance - Occupier

Strength & Durability is affected by:

- In-built vulnerability due to first three phases
- Normal ageing
- Bad maintenance: accelerated ageing
- Environmental factors: rain, saline weather, pollution
- Topographical factors: reclaimed land
- Incidental factors: Alterations, earthquake etc.

A Scenario for Mumbai / Maharashtra: Co-op. Housing Societies:

- Mumbai 80% of upper / lower and middle class: CHS
- Governed by bye-laws adopted by the CHS
- Managing Committee: Control & Responsibility
- Everybody's collective problem is Nobody's individual problem

Purpose of structural Audit is to ensure regular assessment of buildings so that the CHS can take appropriate measures at the right time

Rigorous Assessment of buildings:-

- Condition Survey
- Testing
- Study of arch. And structural drawings
- Preparation of drawing, if necessary
- Checking of design for DL, LL, WL
- Checking for seismic resistance
- Estimation of cost of repair / rehabilitation / retrofitting work
- The first well-defined essential step of assessment
- External / Common: external face, projection, porch, lobby, staircase, elevator shafts, stilts, terrace, water tanks, LMR, ancillary structures and premises.
- Very similar to a your preliminary health check up by your family physician:
- It may lead to a more detailed assessment depending upon its findings & recommendations.

Important Aspects:

- **Mandatory Condition:**
  15 years to 30 years: once in 5 years
  Beyond 30 years: once in 3 years
  Bldgs. with extensions: Period wrt the original bldg.
- Good engg judgment is vital. So Structural Audit should be carried out by senior and experienced engineer.
- Instruments: light tapping hammer, damp detector, spirit level, magnifying glass, binoculars, magnetic compass, plumb, tape & torch and a tape recorder.

Exclusions

- NDT and other tests
- Detailed study of drawings (even if available)
- Preparation of as-built drawings
- Survey of foundation
- Remarks regarding alterations
- Checking of structural design and stability
- Photographs
- Any of the above can be carried out at extra charge

Non destructive tests - Comprise of

- Rebound Hammer Test
- UPVA test
- Core Test
- Chemical tests
- Alkali test of Agrregates
- Carbonation
- Chloride test

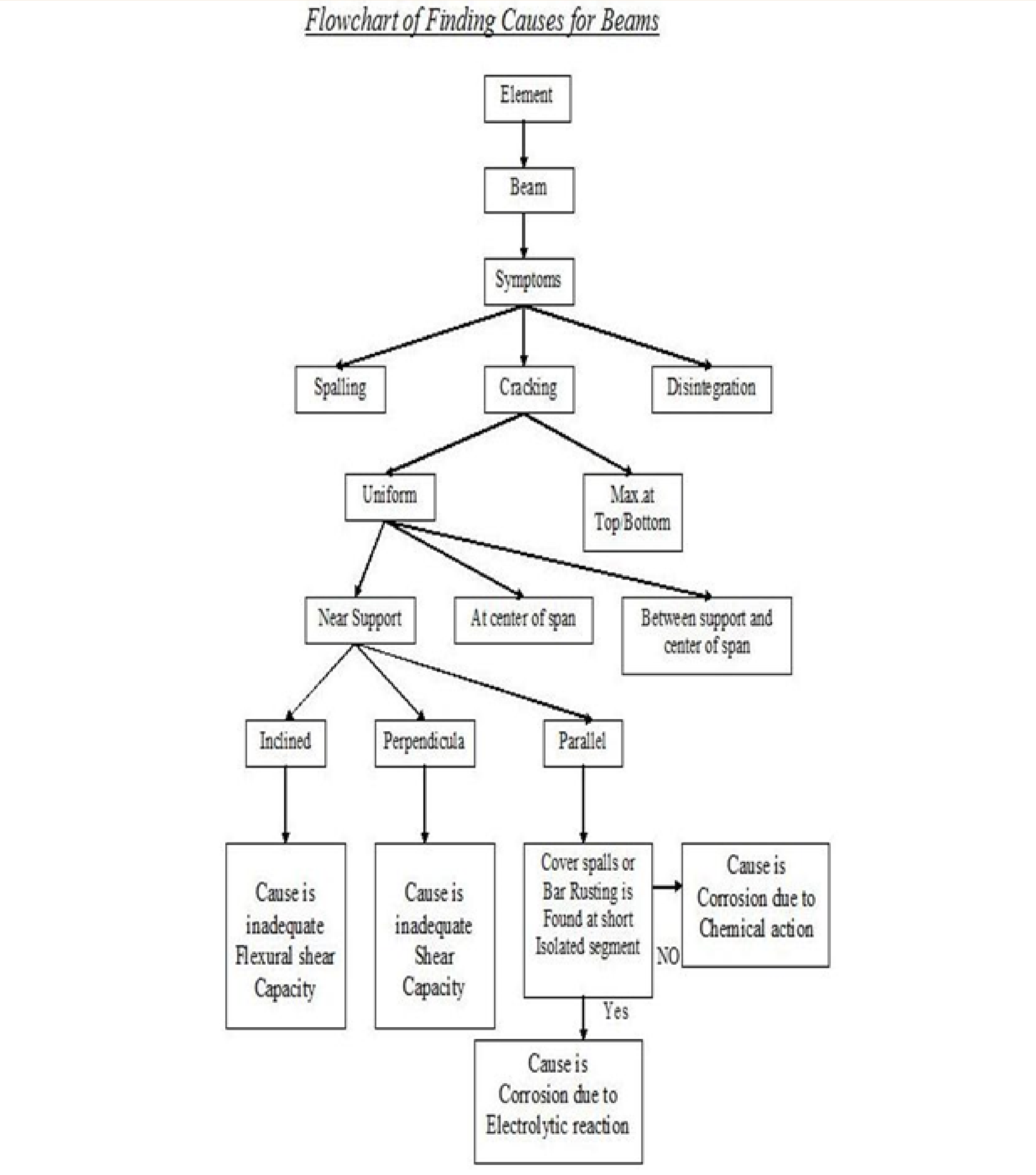

Figure 1: NDT

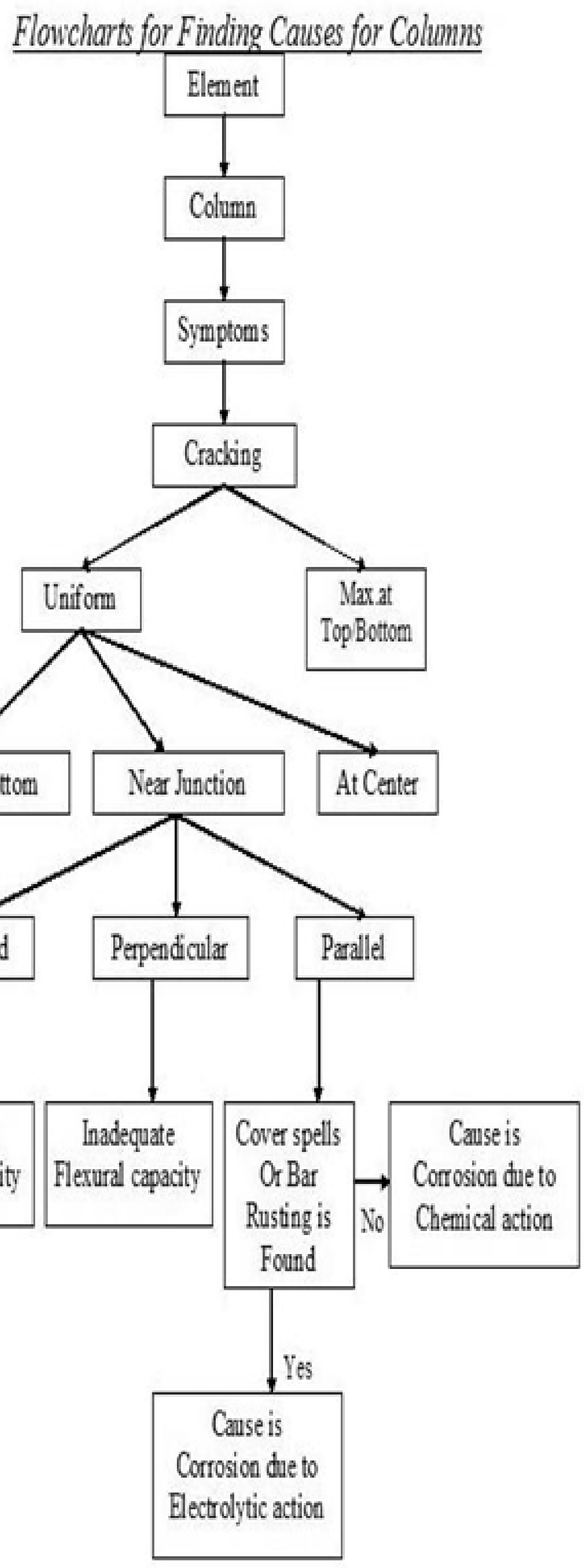
Flowcharts for Finding Causes for Columns
Element
Column
Symptoms
Cracking
Uniform
Max at Top/Bottom
At Top/Bottom
Near Junction
At Center
Inclined
Perpendicular
Parallel
Inadequate Tension capacity
Inadequate Flexural capacity
Cover spells Or Bar Rusting is Found
No
Cause is Corrosion due to Chemical action
Yes
Cause is Corrosion due to Electrolytic action

Figure 2: NDT

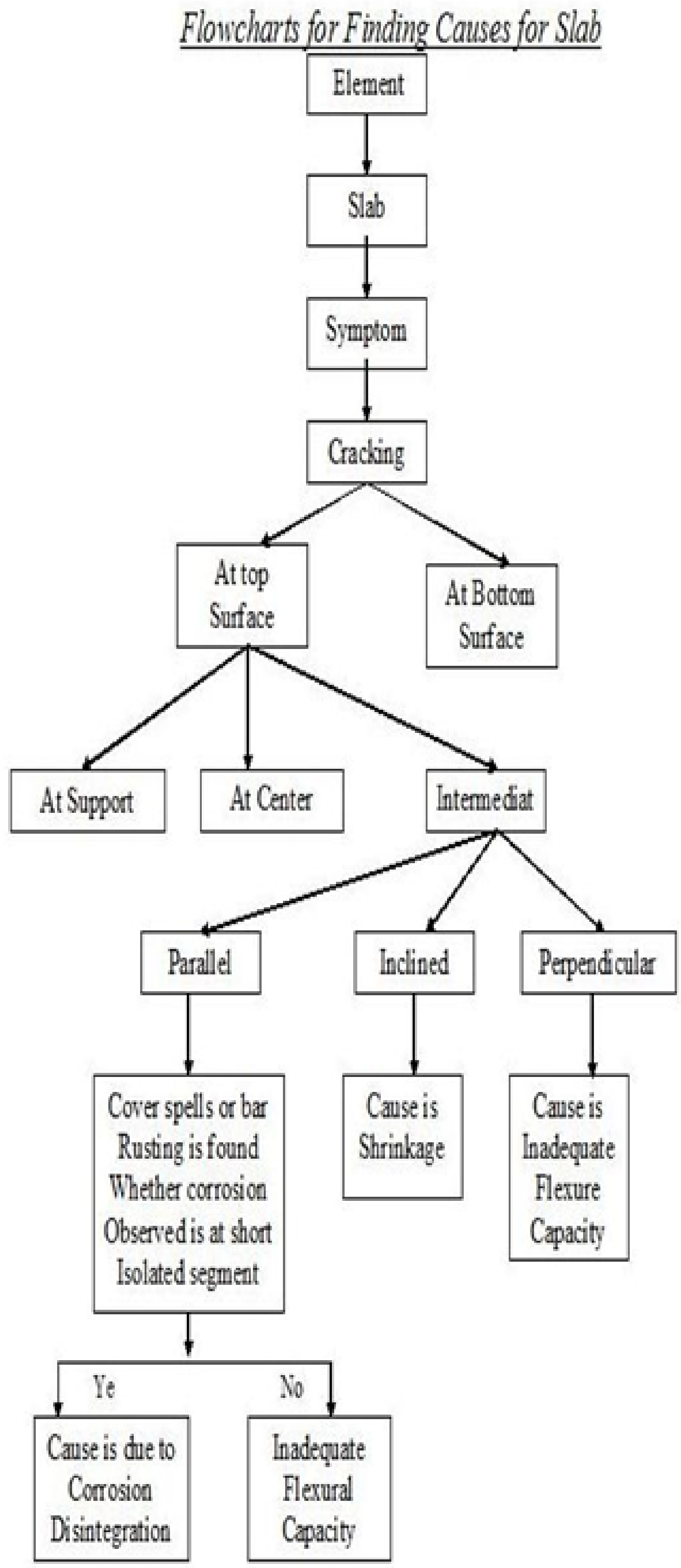
Flowcharts for Finding Causes for Slab
Element
Slab
Symptom
Cracking
At top Surface
At Bottom Surface
At Support
At Center
Intermediat
Parallel
Inclined
Perpendicular
Cover spells or bar Rusting is found Whether corrosion Observed is at short Isolated segment
Cause is Shrinkage
Cause is Inadequate Flexure Capacity
Ye
No
Cause is due to Corrosion Disintegration
Inadequate Flexural Capacity

Figure 3 : NDT

What to Look for:

- Cracks, spalls, bulges, dampness, corrosion
- Buckling of bars of columns
- Excessive deflection, local failures
- Settlement of foundation, Tilting of building
- Load carrying system for major load e.g. OHWT

Probable Location:

- Columns: base, under beam, external / corner columns
- Beam: soffit, sides, at the level of external chajjas
- Beam-Column junctions
- Slabs: Passages, lofts, balconies, toilet, terrace

Observations – Masonry & Plaster:

Masonry:

- Cracks: Diagonal, vertical, horizontal, separation
- Seepage / dampness / Quality of mortar
- Settlement / Damp rising on ground floor / stilts
- Growth of vegetation

Plaster:

- Local absence
- Cracks, Looseness / hollowness
- Seepage / dampness
- Quality of mortar

Main consideration:

- Present Quality
- Adherence to good practices
- Regular maintenance

Items:

- Waterproofing: Terrace, Water tanks, Chajjas, Toilets
- Terrace parapet: Absence of coping, support for pipes
- Drip Mould: Terrace parapet, Chajjas
- Flooring: Loose / cracked tiles, Lifting settlement
- Dado, cladding, skirting: Cracks, hollowness, building
- Plumbing and drainage: Quality of pipes, connections
- Planting: Present quality
- Plinth: Level, settlement, plinth protection
- Absence of chajjas

Excessive load: Mode of use, addl. OHWT, loft tanks, furniture, raised levels, overloading of balcony Pests: Termites / rodents etc. Additions / alterations: Wherever obvious Adverse effects of an earlier repair work.

Common Distress prone Areas:

- Terrace slab
- West and south of sides, Dead walls
- External side of staircase
- Staircase cabin roof
- OHWT and suction tanks
- Lift machine room, pump room
- Porch, chajjas, and elevation members
- Top floor apartments
- Toilet and kitchen areas and lofts
- Balconies

Remark

Overall condition of the building is Satisfactory.
Overall Condition of the building may be satisfactory. The Society is May be one of the following:

- Advised to take up further investigation such as … for further assessment of the building.
- Overall condition of the building is not satisfactory. The Society is advised to take up repair of the building as soon as possible. List of important items of repair: … … Any delay may affect the condition of the building adversely.
- Overall condition of the bldg is so bad that immediate / urgent strengthening / rehab is necessary. Areas needing immediate attention / temporary propping: … … Any delay may further worsen the condition of the building.
- Overall condition of the bldg is extremely bad and it may not be safe for habitation. The Society is advised to take appropriate measures to ensure safety of the occupants.
- Happy Home Society is a small society in MIG colony at Bandra (E). having only one building.
- G + 3, RCC framed structure with one staircase and no elevator.
- 12, 1 BHK apartments with 3 apartments on each floor.

Sequence of External Inspection-

Normal sequence followed:

- Apartments from ground to top floor

- Terrace area
- Staircase area terrace to ground
- Building faces, stilts, lobby, porch etc.
- Ancillary structures: UGWT Pump room
- Paving, compound wall & rest of the premises.
- Living room
- Kitchen
- Toilet area
- Bed rooms & balconies

While visiting apartments, carry a copy of the appointment letter & the Notice for identification.

Notes:

1. The reports marks the completion of Struct Audit.
2. Inspection of foundation & seismic assessment are beyond the scope of Structural Audit.

Tools Used

Tools used for Inspection are:

- Light tapping hammer
- Damp detector
- Spirit level
- Magnifying glass
- Magnetic needle
- Plumb
- Binoculars

Structural Audit: A Case Study

Enquiry for Structural Audit

Distress Observed: Apartments

- Seepage of water through terrace slab and canopy
- Structural distress: Loss of cover, exposed and corroded reinforcement especially in beams and slab in the toilet area
- Kitchen dado was loose and sounding hollow at some places.
- Up to 3 ft. long vertical cracks at bottom of some Internal columns.
- Alterations: Conversion of original kitchen into bedroom, removal of wall to enclose balcony, raising floor…..

Internal Inspection: Constraints

- Recent renovation work in some apartments: No distress was visible.
- Tile cladding, false ceiling, panelling, fixed or heavy furniture etc.,
- Apartment found locked: 1 first floor Entry refused: 1 ground floor It took nearly 3 hours to Inspect the apartments: 15 minutes per apartment.
- Columns and beams supporting OHWT were badly damaged, showing loss of cover concrete & exposed, corroded reinforcement. Water was found dripping from the beams.
- Terrace waterproofing: South half: Conventional type + china mosaic North half: Chemical without brick bat coba
- As reported by the occupant below: during the previous repair work, the structural quality of the slab was suspected to be very bad & incapable of carrying the load of the bb coba.
- Excessive seepage and dripping during monsoon was reported in the top floor apartment
- Closer inspection of the slab revealed that the quality of concrete was very bad and it may have to be recast.
- The quality of plaster on the terrace parapet was also poor and there was no drip mould or coping beam provided.
- The column in wall exhibited crack.
- Beam supporting the staircase cabin slab showed cracks at bottom
- There were wide cracks at the bottom of staircase cabin roof slab and the slab was beyond repair.
- Staircase flight, slabs & mid-landing beams showed cracks, loss of cover and corrosion.
- Cracks were seen in staircase cabin walls.
- Electrical conduits were corroded.
- RC jali was broken at some places.
- Structural Cracks in corner columns throughout the height.
- Cracks at some beam-column junctions
- Structural quality of chajjas was very bad. Reinforcement was exposed & corroded. There was vegetation on top of chajjas & chajjas were beyond repair.
- Structural cracks in Canopy slab
- Seepage through canopy reported
- Balcony pardi showed structural cracks.
- Building is not painted recently externally.
- Quality of ext plaster was very bad. No plaster at some places.
- Faces were not in plumb.
- No RCC chajjas for some enclosed balconies.

- Plinth protection: Only partial & cracked External Inspection was completed in 2 hrs.

Remarks in Audit Report

- We feel that overall condition of the bldg is so bad that urgent rehabilitation is necessary.
- The north half of terrace slab needs immediate attention. This part of the slab may have to be recast. Any delay may further worsen the condition of the slab and may prove to be dangerous for the occupants in that apartment."

Action on structural Audit Report

Because of the severity of distress and our remarks, the Happy Home Society decided to take up repair work immediately and thus our role as auditors was truly complete.

Some Examples from Aurangabad

- Terrace at one G+3 apartment Building at N-1 CIDCO Aurangabad
- Water tanks at terrace with RCC slab roof

Figure 4 : Terrace at one G+3 apartment Building

Figure 5: Water tanks at terrace with RCC slab roof

Durability

Means structure will continue to perform its intended functions, maintain its required strength and serviceability during expected life span.

1. life span 120 years for a major tunnel
2. 50-60 years for industrial structure
3. Temporary structure

Causes of deterioration

1. External
   mechanical impact, abrasion, erosion,
2. Internal
   Chemical : Alkali silica reaction or alkali carbonate reaction both are chemical action.
   a) Chlorides and carbon di oxide in the form of mild carbonic acid causes corrosion of reinf.
   b) Physical: repeated cycles of freezing and thawing and temperature effects.

High temp differential between different parts of concrete member. It is how impervious your concrete is, the durability matters.

Strength: We always talk of a good strength and achieve it also, but an excellent strength.

does not mean it is durable, or a concrete is durable does not mean, it has a good strength. Neither guarantee each other

Factors to enhance durability

1. Cement content per cum
2. Amount of water w/c ratio .
3. Size of aggregates
4. Achieve low penetrability of concrete
5. Curing most imp.

Maintenance:

Every structure needs to be maintained. Unlike steel structure which gets painted. (SYDNEY BRIDGE)

Concrete needs it. Structures built in 60 and 70s are less durable and need much repairs. Regular structural auditing.

Conclusion

We can make durable concrete by use of good cementitious materials, appropriate admixtures, super plasticizers, and proper cover to reinforcement, compaction of concrete, adequate mixing time, and curing. Proper batching, transporting, placing, compacting, finishing, up to curing.

ER. N G Karkhane - Karkhane & Assosiates, Aurangabad

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1992-Today- Working as Structural designer in Aurangabad city for residential, commercial and industrial building constructions. Presently involved in Industrial buildings at Gujrat, Baramati, Jammu & Kashmir.

Appointed as a structural design Authority by Government of Maharashtra for water supply departments of ZP and MJP. Under tanker free schemes of Govt, designed elevated storage reservoirs, all kinds of water storage reservoirs, almost more than 500 no of ESRs (ngkarkhane@gmail.com)

Performance Characteristics of Site Blended Fly Ash Based Concrete and Factory Manufactured PPC Concrete - A Comparative Assessment

S. A. Khadilkar

A proper insight into the possible mechanisms of concrete deterioration has led to altering of the properties of OPC concrete through the beneficial use of the blending components like fly ash, GGBS, Metakaolin etc so as to achieve an improved performance of resultant concrete.

Fly ash based cement concrete made either with the blending component as a part in cement or alternatively as site blended at the Ready - Mix locations, the blended concrete is becoming an accepted option for a durable civil structure.

There has been always a comparison of the concrete made with factory produced inter ground PPC and site blended fly ash based concrete, with respect to their performance characteristics and opinions have always been divided on the issue.

Considering that the fly ash as produced is a finer product, inter blending of the fly ash with ground OPC has been considered to be better in performance as compared to a fly ash cement produced by intergrinding of fly ash, clinker and gypsum. This is however dependent on the characteristics of the fly ash, such as its particle size distribution, amorphous contents and its extent of variability in terms of its chemico-mineralogical compositions.

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. 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 fineness of the fly ash from the different thermal plants in the country ranges from 12% to 50% residue on 45 microns. In this scenario use of the site blended option has its limitations.

On the other hand the intergrinding route puts forward an opportunity to optimize the fly ash particle characteristics in the Blended Cement product (PPC), so as to maximize the pozzolanic potential of the available fly ash.

Selective use of classified fly ash for producing PPC is limited by the quantum availability of the desired quality of fly ash for the manufacture of PPC through the inter blending route due to which the interground product is the preferred alternative.

Use of classified fly ash at site in concrete directly (site blending) also suffers from limitations of inhomogenous distribution of the lighter fly ash component with the concrete components, proper control on the proportions of usage of fly ash at such site blending locations is also a cause of concern.

On the other hand intergrinding (or co-grinding) of fly ash, clinker gypsum provides a means of having a more consistent product with a good control on variability thus with better performance Characteristics.

At the R & D Division of the Research & Consultancy Directorate of The ACC Ltd , studies carried out have helped evolve an understanding of the influence of the properties and reaction mechanics of the fly ash component in determining the limiting / favoring conditions for improved concrete properties related to its durability and it could be stated with a high degree of confidence that in the inter-grinding mode, with use of proper methods for reducing the variability in chemico - mineralogical composition of fly ash, optimization of the comminution system to achieve the desired distribution of fly ash in the size fractions of the composite cement, enhances the pozzolanic activity fly ash and helps improve the performance of the resultant Pozzolanic cement.

The intergrinding process also helps to mechanically activate the fly ash by creating new reactive surfaces during comminution, it helps to improve the sphericity of the coarse angular fly ash particles (rounding of the angular particles) (1).

In the fly ash based blended cement production by intergrinding mode, some interactions are reported to occur between the particles of the different ingredients during grinding (mechanochemical activation). As a result of these interactions, particle size distribution of inter ground blended cements is different than that of interblended cements of the same composition and fineness.

Turker et al (2) and Popović et al (3) studied the influence of separate and intergrinding of cement and pozzolanic materials.Cements having the same composition but produced by intergrinding and separately grinding were compared from compressive strengths and microstructure of hydration points of view of resultant PPC and concluded that for pozzolan based cements grinding method affects the microstructure of hydration significantly. Paya et al (4) and Songrpiriyaki (5) reports that grinding of fly ash reduces the fly ash particles to a size range at which it reduces the water requirements in concrete, the finer size fractions improve the early age compressive strengths of Mortar as well as concrete. The comparison could be extended to performance of concrete made with Factory manufactured PPC and the site blended concrete product.

The differences in performance of concrete made with Factory produced PPC and site blended fly ash concrete could be due to the following.

1. Variability in percentage fly ash component due to either impoper control on the cementitious components or due to improper mixing.
2. Due to inferior quality of the fly ash used in site blending operations or due to variability in fly ash characteristics , which would produce a difference in the hydration kinetics of the fly ash component of the cement paste matrix of the concrete.

The first aspect can be taken care to a large extent in well controlled RMC operations but the second aspect would still remain unattended in absence of availability of a processed fly ash of desired particle characteristics. Thus even in a RMC operations the quality of fly ash used could bring about a difference in the site mixed concrete and concrete made with a factory produced PPC. If in a RMC operations if processed fly ash is used of desired particle characteristics and of controlled variability in the chemico - mineralogical characteristics the differences in the site mixed and factory produced PPC based concrete would be minimal.

In order to understand this difference in two concrete a comparative study was carried out at RCD which is discussed below in some details, illustrated by the mortar and concrete properties. Study of the differences produced in the reaction chemistry and resultant cement paste microstructure, which determine the performance and durability of the resultant concrete has also been attempted.

Concrete taken for studies

Concrete - 1

Factory manufactured PPC with engineered particle size Distribution (PPC)

Concrete - 2

Site blended with OPC & Fly ash (of the same source with different particle size distribution) (OPCFA)

The chemical composition of clinker and fly ash used in the manufacture OPC and PPC of the same Cement Plant is summarized in Table -1 The particle size distribution of OPC , PPC and Fly ash is given in Table - 2.

Table 2: Particle size Distribution of cements & fly ash

Size (microns)	OPC	Fly ash	PPC
> 210	0.2	0.2	0.0
150	1.5	2.7	0.4
90	6.2	10.2	1.8
60	14.2	24.2	8.5
45	20.6	36.2	15.0
30	28.9	44.5	23.7
20	45.7	56.5	38.8
10	67.0	71.5	64.7
5	87.0	91.5	91.1
2	94.2	98.7	98.3
< 2	5.8	1.3	1.7

Table 1: Chemical composition of clinker & Fly ash

%Oxides	SiO2	Al2O3	Fe2O3	CaO	MgO	LOI	Na2O	K2O	SO3	I.R	LSF	SM	AM
Clinker	21.6	4.7	3.4	64.0	4.7	0.3	0.05	0.63	0.3	-	0.94	2.67	1.38
Fly ash	65.1	23.1	5.3	0.8	1.0	2.2	0.07	0.65	0.15	93.9	-	-	-

The hydration characteristics of the factory produced PPC (26% fly ash) and the cement mixture OPCFA (OPC + 26 % Fly ash) represents the expected hydration kinetics of the Cement Paste Matrix (CPM) in the resultant concrete.

The evaluation carried were as follows:

- Pozzolanic activity of the fly ash component in the cements at different ages of hydration through monitoring of the free Calcium hydroxide contents.(Fig.1)
- % Reaction of the fly ash component in the hydrated neat cements up to 28-days of hydration.(Fig.2)
- Assessment of alkalinity (pH) of the hydrated neat cement pastes at different ages of hydration. (Fig.3)
- Morphology & microstructure of the cement pastes by Jeol JSM 5400 Scanning Electron Microscope.(Plate -I Plate – II)
- Comparative Mortar properties of the PPC and OPCFA (OPC + Fly Ash mix) (Fig.4)
- Comparative properties of PPC concrete and the OPC+fly ash (site mix) (OPCFA) concrete (Fig.5 & 6)

Hydration studies

Neat cement pastes of the PPCs were cast (w/c=0.38) and de-molded after 1-day and cured for different ages of hydration i.e. 1, 3, 7 & 28 days.

At each age of hydration the neat cement pastes were evaluated for:

- Free calcium hydroxide content in the hydrated cement pastes at each age as determined by ethylene glycol extraction method .
- The unreacted fly ash in hydrated cements at each age of hydration as determined by picric acid - methanol extraction method

The unreacted fly ash in hydrated cements was evaluated using picric acid methanol method as reported by S.Li et al (6) and was also used by the RCD to study the pozzolanic efficacy of fly ash. (7,8,9 ,10) in the hydrated cement at different age of hydration. The brief method is given below:

A known weight the hydrated neat cement was treated with aqueous - methanolic picric acid solution with magnetic stirring for a fixed time of 30 minutes. The residue was filtered and washed free of picric acid with methanol and subsequently washed with 300 ml of water at 500 C. The residue was dried and ignited at 1000 o C. The residue was weighed after cooling. The residue in the blending components was determined by the same method separately. Based on the residues of the Blending component and the Blended cement at each age of hydration the % unhydrated and % hydration of the blending component was computed.

The pozzolanic reactions of the fly ash gradually results in consumption of the calcium hydroxide, produced from the hydration of the OPC part of the blending cement as a result there is a decrease in the calcium hydroxide contents of the hydrated cements, which in turn is reflected in decrease in the unreacted fly ash content in the hydrated cement paste.

Thus the free calcium hydroxide contents of the hydrated cement pastes would be related to the pozzolanic reactivity of the blending component at that age of hydration. This would also correspond to the % reaction of the fly ash component in the fly ash based cement.

Results And Discussions

The free calcium hydroxide contents of the hydrated PPC & OPC+Fly ash mix , at different ages of hydration is graphically shown in Fig.- 1. The un reacted fly ash in the hydrated cements at different ages of hydration was analysed, and the computed % Reaction in different hydrated cement pastes was calculated and is graphically depicted in Fig - 2.

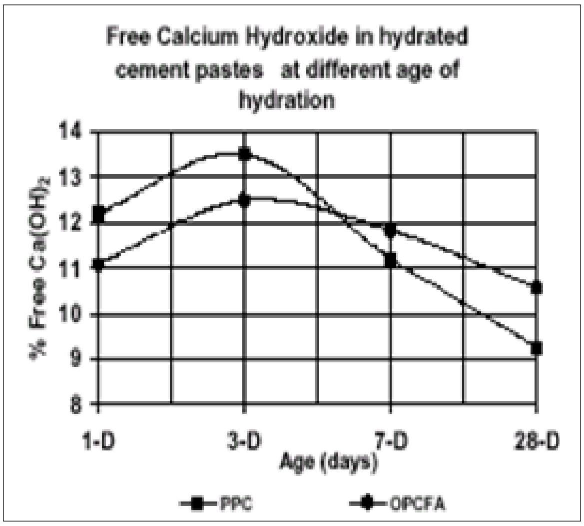

Figure 1: Free hydrated lime content in Hydrated cement pastes

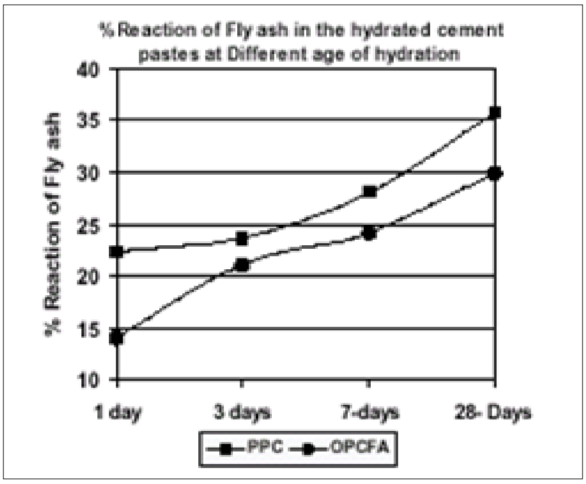

Figure 2: % Reaction of fly ash in the hydrated cement pastes.

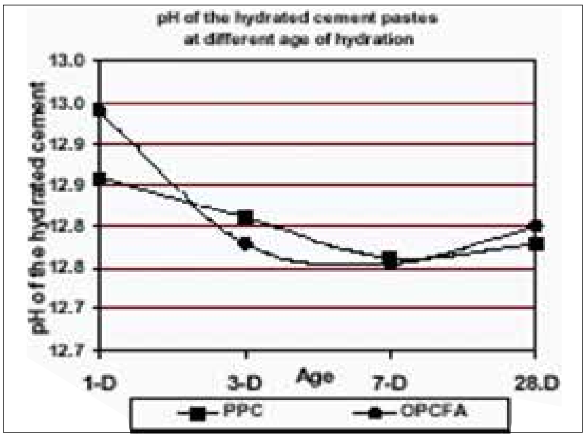

Figure 3: pH of the hydrated cement pastes

The % free hydrated lime present in the hydrated cement paste (Fig-1) and the % reaction of the fly ash t (Fig-2) indicates that PPC comparatively shows higher reactivity of the fly ash than OPCFA (site mix).

The alkalinity (pH) of the hydrated neat cement pastes at different ages of hydration was measured by pH electrode at w/c ratio of 0.38 and is graphically shown in Fig.3. The observation indicate the pH to be highly alkaline (12.7-12.8).

Morphology and Microstructure:

The hydrated paste micro-structure of the different cements at 3 & 28 days of hydration is illustrated in the photomicrographs shown in Plate . I & Plate II and the salient observations on the microstructure is summarised below :

Hydrated PPC & OPCFA at 3-days:

- At early ages of hydration i.e 3 days significant presence of long needle shaped Aft crystals in the pores spaces are observed in PPC (Plate : I a) as compared to OPCFA (Plate Ib).
- Platelets of CH crystals with rounded fly ash particles with surface reaction products like gel type of CSH has been observed more in PPC (Plate I a).

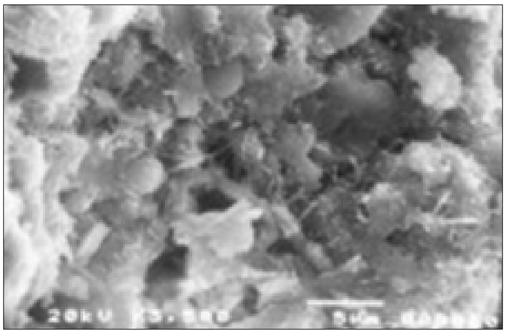

Plate I a : 3-days hydrated PPC

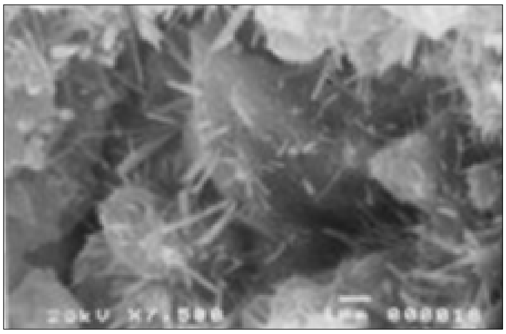

Plate I b 3-days hydrated cement OPCFA

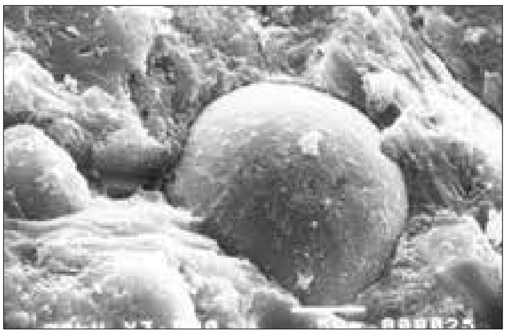

Plate II a: 28-days hydrated cement PPC

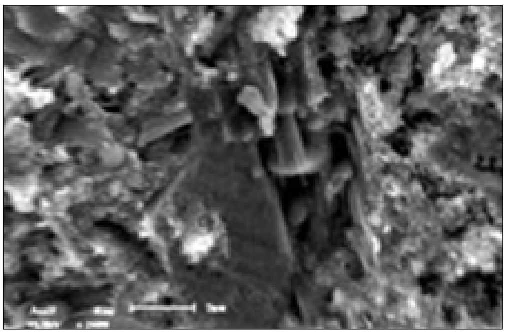

Plate II b: 28-days hydrated OPCFA

Figure 4: Mortar properties

- The porosity is more in OPCFA (Plate I b)
- Portlandite crystals are also seen in both the cement pastes.

Hydrated PPC & OPCFA at 28-days:

- The hydrated PPC paste at 28 - days, shows highly dense and compact hydrated mass is observed especially in PPC where the fly ash component shows more reactivity , due to which there is high degree of networking of fibrous and thin plate like CSH intermixed with Aft, Afm and CH (Plate II a,)
- OPCFA (Plate II b) comparatively shows more partially hydrated fly ash particles with few large Portlandite crystals , the hydrated mass is observed to be less compact.
- As the hydration proceeds the pores gradually get filled and become more denser due to development of more CSH (both fibrous and gel type) and Aft crystals filling the pores

Mortar Properties:

Comparative Mortar properties of PPC & OPCFA is shown in Fig. 4. The data indicates that PPC has higher strengths at all ages as compared to OPCFA indicating the merits of improved properties of the PPC (inter ground fly ash based cement) , due to better packing and increased reactivity of the fly ash component.

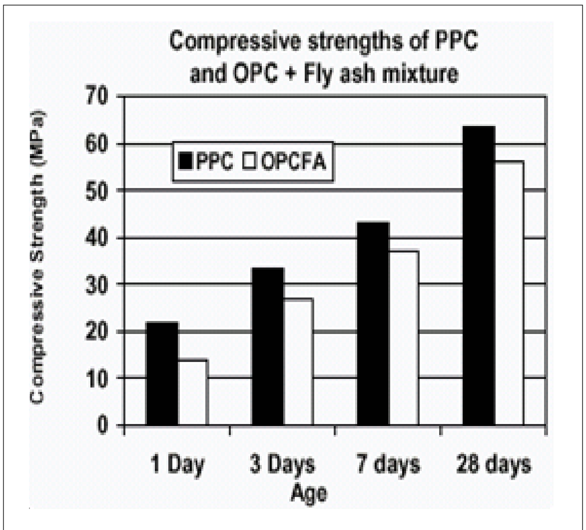

Figure 5: Comparative Mortar strengths (IS STD)

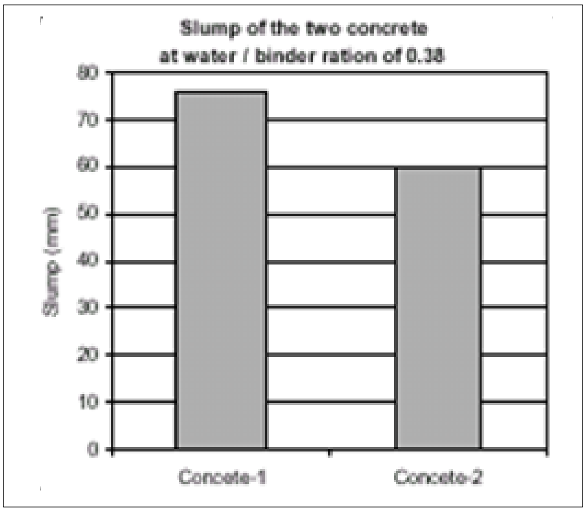

Figure 6: Slump

Concrete Properties:

The cements were subjected to concrete evaluation. The M-25 grade concrete was made with PPC & with OPC + Fly ash (site mix)and . Fig.5shows the difference in slump of concrete and Fig.6 shows the compressive strength.

The results indicate that the concrete with PPC (26 % fly ash) shows improved workability compared to the site mix concrete with same fly ash (26% fly ash). The PPC concrete also shows higher strengths

This is substantiated by the observed compacted microstructure resulting from the packing effect of the finer fractions of the fly ash and improved pozzolanic reactivity of the fly ash.

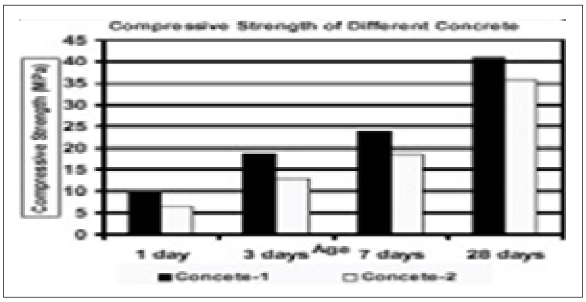

Figure 7: Concrete Properties

Conclusions.

The studies discussed above illustrates that a factory produced PPC with engineered particle size distribution performs comparatively better than a site mix concrete at similar levels of fly ash , this is primarily because the particle characteristics of the fly ash in PPC is much more finer than the fly ash used in site mix concrete.

The particle characteristics and mineralogy of the OPC & fly ash , alters the chemistry of hydration as well as the pore filling / packing tendency of the fly ash in the hydrated Cement paste matrix, which determines the performance of the resultant Concrete .

Another aspect of importance in a factory manufactured PPC is that with the upper limit of BIS going up to 35%, the gypsum component is appropriately adjusted so as to derive the maximum potential from the aluminous component of fly ash (through optimization of SO3) , in a site mix mode no such gypsum additions are resorted and neither are they possible. It is well studied and reported in literature that at higher fly ash levels gypsum requirements are higher, in which case in the site mix mode one would lose this contribution of hydraulic/pozzolanic potential from fly ash based blended cementitious system. which would not be the case in a factory manufactured PPC based concrete.

In view of the variations in the characteristics of the fly ash available from the coal fired thermal plants in the country, the intergrinding based factory produced PPC option, would be more preferable as it would produce a more consistent product .

The site mix mode of use of fly ash would be suited in RMC locations if these locations use a processed fly ash of consistent quality, if such a consistent quality of fly ash of desired particle characteristics is made available along with a consistent OPC compatible with the fly ash , the concrete produced could be similar to a factory manufactured PPC concrete, except for the gypsum deficiencies.

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Durability of Concrete Roads Constructed with Blended Cements

Anurag Sullerey

Blended cements not only enhance the life of concrete roads by protecting them from chloride and sulphate attacks, but also reduce thermal cracking, plastic and drying shrinkages that are common with Ordinary Portland Cement (OPC) constructions. This paper highlights the benefits of using blended cements in road constructions. Using such cements in rigid pavements is not only technically acceptable but also environmentally friendly.

One of the advantages of concrete roads is the lower lifecycle cost compared to bituminous roads. Yet in India, the ratio of concrete roads to bituminous ones is abysmally small. This is mainly because the initial construction cost of concrete roads is higher than that of the bituminous roads. Earlier the cost used to be higher by 20-30 percent but now, owing to new design methods and technologies, this has reduced to 10-15 percent. However in choosing the pavement type - flexible or rigid - highway administrators and engineers also look at the availability of the binder material. Bitumen, a by-product from petroleum crude processing, is in short supply globally and its price has been rising. Nearly 70 per cent of India's petroleum crude is imported.

The demand for bitumen in the coming years is likely to grow, far outstripping the availability. Therefore, it will be in India's interest to explore alternative binder materials for road construction. Although cement is available in sufficient quantity in India, the country has not exploited this advantage. Incidentally, India is the second largest producer of cement in the world after China.

Besides favourable availability factor of cement, concrete roads trump bituminous ones because of longer life cycle and being maintenance-free. In addition, they can withstand extreme weather conditions such as temperature fluctuation, heavy rainfall and water-logging, better than bituminous roads.

Earlier, concrete road constructions used ordinary Portland cement (OPC) with high compressive strength. Despite having many inherent advantages, the use of blended cements in road construction was discouraged because of their slower rate of hardening. However, today technological developments have overcome this limitation. Cement manufacturers now produce blended cements with strength gaining properties almost at par with OPC. Blended cements with high chemical resistance are eminently suitable for road construction. Besides, such cements reduce the carbon footprint of road construction, qualifying as environment-friendly binders.

This paper discusses the benefits of using blended cements in road construction and suggests that highway construction in India should use them with confidence. Successful examples of road construction using blended cement are many, around the world.

Road network in India

India has about 3.3 million km of road network. These roads occupy an eminent position in the transportation sector as they carry 65 percent of the freight and 85 percent of the passenger traffic.1 According to one estimate, road traffic is set to grow at a rate of 7 to 10 percent per annum while the vehicle population is expected to grow at a rate of 10 percent per annum.2 Therefore it is needless to emphasize the importance of road transportation. Inefficient transportation means missing international competitiveness. An estimate suggests that the economic losses to the national exchequer caused by sub-standard and inadequate roads was more than Rs. 20,000 crores per annum. In the last 45 years, the total length of roads in the country has increased seven-fold. However, the national and state highways, which carry the majority of traffic across the country, have increased about 2 times only.

Even though national highways form less than 2 percent of our road network, they carry about 40 percent of the total traffic.3

The Indian Road Network is given in Table 1.4

Concrete roads in India

Of the 3.3 million km road length in India, the share of concrete roads is very small. Two programs that have given a boost to road construction projects in India are the National Highway Development Program (NHDP) which carried out the famous Golden Quadrilateral Project 5864 km (almost completed) and the NSEW corridor 7300 km (completed 4863 km) in its first phase and the Pradhan Mantri Gramin Sadak Yojana (PMGSY).

The advent of expressways and four-lane projects have provoked a profound paradigm shift in road construction.

Concrete roads can contribute to the paradigm shift with the following advantages:

- Long service life – more than 40 years
- Increase strength with age
- Resistance to oil, chemicals and weather
- Ability to withstand heavy axle loads without rutting
- Resistance to sub grade failure by spreading wheel loads
- Excellent light reflection providing greater visibility
- Cost-effective design and construction
- Built-in skid resistance and improved traction
- Ability to meet specific design life requirements
- Adaptability to use locally available raw materials which can also be recycled, thus saving scarce resources.
- Withstanding extreme weather conditions (such as wide-ranging temperatures, heavy rainfall and water-logging) better than bituminous roads.

Until the year 2000, the Ministry of Road Transport and Highways specified that OPC-33, OPC-43 and OPC-53 cements should be used for concrete road construction, with a pReference for using OPC 43 or higher grades. However, now this has changed. The revised specification through amendment no. 3 to IRC:21-2000 by Indian Roads Congress - 2008 allows blended cements such as the Portland Slag Cement (PSC) and Portland Pozzolana Cement (PPC) along with OPCs to be used in highway constructions. Notwithstanding this change, the agencies engaged in executing highway contracts continue to prefer OPC 43 grade because of the old stipulation.

Table 1. Road network in India

Types of Road	Total Lenght
Expressways	200 km
National Highways	70,542 km
State Highways	1,31,899 km
Major District Roads	4,67,763 km
Rural and Other Roads	26,50,000 km
Total	33,20,404 km

Blended Cements

Blended cements or composite cements have a mineral component added to Portland cement. They are therefore similar to OPC but offer improved properties.

The normal reactions of blended cement with water are:

Primary Reaction

2C3S+6H= C3S2H3+3Ca (OH) 2 .....(1)

2 C2S+4H= C3S2H3+Ca (OH) 2 .....(2)

Secondary Reaction

POZZOLANA/SLAG+3Ca (OH)2=C3S2H3....(3)

OPC shows only the primary reaction, which liberates lime. Because the compounds of such reactions are weak in resisting chemical attacks such as sulphate attacks, concrete becomes prone to expansion and cracking. In other words, using OPC alone could introduce an element of risk in concrete durability.

On the other hand, cements with pozzolanic materials undergo a secondary reaction. By combining with lime, they yield hydration products that have higher ultimate strength and denser CSH microstructure. The secondary reaction modifies the pore structure and pore size distribution to make the concrete micro-structure more dense and hence impermeable, resulting in better durability.

In other words, blended cements offer improved impermeability of concrete, better resistance to chemical attack and reduced alkali-aggregate reaction.

Portland Pozzolana Cement (PPC)

Portland Pozzolana Cement manufacturing involves both grinding and blending of Portland cement clinker and fly ash.

The Bureau of Indian Standards (BIS) IS:1489 July 2000 amendment specifies addition of fly ash in cement between 15-35 percent by weight of cement.

Advantages of using PPC in concrete roads, according to NCCBM

The National Council of Cement and Building

Materials (NCCBM) finds the following advantages in using PPC in concrete road construction:

Reduced Cement Consumption:

By carrying out proper mix design with high strength PPC, cement consumption can be reduced.

Improved Mechanical Properties:

Concrete made with cement containing fly ash develops better mechanical properties with proper curing. The increase in compressive strength of PPC concrete was 61, 95 and 94 percent compared to 43, 57 and 45 percent for normal concrete at later ages of 90, 180 and 365 days respectively. In addition, flexure strength and the modulus of elasticity of fly ash concrete also increased.

Improved resistance to chemical attacks:

PPC concrete shows better performance when exposed to sulphates and chlorides than OPC concrete.

Less drying shrinkage:

Drying shrinkage is lower in concrete made with PPC.

PPC concrete is impermeable and hence more durable.

Other advantages of PPC concrete are: PPC acts as a water reducer: The water requirement for a given consistency reduces due to the presence of fly ash. Three mechanisms explain this phenomenon. First, fine particles of fly ash adsorb on the oppositely charged surface of cement particles and prevent cement from flocculating. As a result, they do not trap a large amount of water. This means that the system's water requirement reduces for a given consistency.

Secondly, the spherical shape and smooth surface of fly ash particles help to reduce the particle friction and improve workability.

Finally, the particle packing effect is also responsible for water reduction. Since both cement and fly ash particles are in 1-45 micron range, they serve as fillers in void spaces in the aggregate mix. In fact, due to its lower density and higher volume per unit mass, PPC is more efficient in void filling than OPC.

Prevents drying shrinkage:

PPC resists drying shrinkage cracking which is commonly encountered with the use of ordinary Portland cement concrete. Drying shrinkage increases if cement paste in the concrete mix increases. It also increases if water in the paste increases. Due to significant reduction in water requirement, the total cement paste volume in PPC concrete is lower than that in OPC concrete.

Improves water tightness and durability:

The resistance of a reinforced concrete structure to corrosion, alkali aggregate expansion, sulphates and other forms of chemical attacks, severity of which depend on impermeability of the structure, or the degree of watertightness. The amount of supplementary cementing material, curing regime and type of cracks in concrete influence the permeability.

Prevents thermal cracking:

Structures that need mass concreting are prone to thermal cracking if OPC is used as the binder. The physical and chemical characteristics of OPC are such that the heat of hydration is greater at an early age. The climatic conditions in India and other tropical countries induce thermal cracking if thermal effects in OPC concrete are not controlled. PPC is a better option in such situations.

Portland blast furnace slag cement (PSC):

Portland blast furnace slag cement is a finely ground mixture of Portland cement clinker and granulated blast furnace slag, either inter-ground or ground separately and then blended. Slag is a non-metallic by-product obtained by rapidly quenching in water the molten slag tapped from the blast furnace of a steel plant. According to Bureau of Indian Standards BIS 1S:455 May 2000 amendment, the slag in PSC could be between 25-70 percent of the Portland cement.

PSC for concrete roads

The world production of slag is approximately 200 million tonnes per year. However, the utilization rate of this cementitious material is less than 40 million tonnes per year, because in many countries only a small quantity of slag is available in the granulated form that is suitable for Portland cement replacement in concrete.5

Influence of blast furnace slag (PSC) on properties of fresh concrete

Concrete made with ground granulated blast furnace slag (GGBS) is more cohesive due to better dispersion of the cementitious particles and the surface characteristics of the slag particles, which are smooth absorb little water during mixing. PSC contains more silica and less lime than ordinary Portland cement. Hydration of blended cement produces more C-S-H gel and less lime than OPC alone. The resulting microstructure of the hydrated cement paste is dense. The harmful effects of high heat of hydration on the long-term strength and permeability are less pronounced in PSC concrete.

Durability of PSC concrete

Durability tests on PSC concrete have shown good resistance to chloride ion penetration.6

Daube and Bakker have shown that the diffusion coefficient of the concrete exposed to chloride ions was about one-tenth of that with OPC concretes when slag content was 60 percent by mass of cementitious material and the water/ cement ratio was 0.50.7 Because of the improved microstructure of PSC, hydrated paste and its low calcium hydroxide content, the resistance to sulphate attack improved.

Hooton and Emery reported that PSC with 50 percent by mass of slag, 7 percent Al2O3 and 12 percent C3A exhibits the same sulphate resistance as sulphate resisting cement.8

The low penetrability of slag cement concrete is also effective in controlling the alkali silica reaction as the mobility of the alkalis reduces in such concretes.

Using PSC for concrete roads is not in vogue worldwide because of the limited availability of ground granulated blast furnace slag. However, in India, ggbs is available and slag based cements can be satisfactorily used in concrete roads. PSC cement of higher compressive strength is also now available in the market.

As there is an increased awareness about sustainability in our societies, high volume fly ash (HVFA) is also gaining attention in road construction.

Concrete roads made with blended cements

The Canada Center for Mineral and Energy Technology (CANMET) has played an important role in developing supplementary cementing materials. The term high volume fly ash (HVFA) concrete was coined by Malhotra at CANMET in the late 1980s. This concrete has very low water content and at least 50 percent of the Portland cement by mass is replaced by Fly ash (ASTM class F, low calcium fly ash). The HVFA concrete has excellent workability, low heat of hydration, adequate early age strength and high later age strength, low drying shrinkage and excellent durability characteristics that are important for the sustainable concrete required at present.

The first HVFA concrete road in India was constructed in Ropar, Punjab and the details of the same were published in this journal.9

Inspired by the pioneering work at Ropar, HVFA roads were constructed in Chhattisgarh interconnecting lanes of a residential colony and a school at Bhatapara near Raipur.

The details of this road are as under:

- Length: 1.2 km.(200-300 m. in each lane)
- Pavement thickness: 150 mm. (not subjected to heavy vehicles)
- Year of construction: 2004

The road was designed as per existing IRC specifications. The pavement concrete was laid directly over a dry lean concrete base of 50 mm thickness.

Fly ash from NTPC Korba was used. The physical and chemical properties of the fly ash used are given in Table 2. Nearly 50 percent of the Ordinary Portland cement 53 grade was replaced with this fly ash to produce HVFA concrete. Laboratory tests and trials were conducted before undertaking the actual work to arrive at the optimum proportion of cement and fly ash. Local aggregates were used in the construction.

HVFA concrete achieved compressive strength of 38 MPa at 28 days. Tables 3 and 4 give mix proportion and properties respectively. The road is performing satisfactorily since 2004 needing no maintenance. It has withstood aggressive summer temperatures of 45-47 degrees centigrade and wet rainy seasons with average rainfall of 1200 mm without showing thermal or shrinkage cracks. Figures 1 to 3 are the testimony to the fact of HVFA concrete makes durable and sustainable concrete roads.

Conclusion

The criteria for using blended cements should not only be viewed in terms of energy saving and resource conservation, but also in terms of the technical benefits including durability. Since the advent of high strength PPC and PSC, either of these cements could be used in pReference to OPC with due regard to economic and environmental considerations. The ambitious highway projects of India could derive benefits from the technical properties of blended cements in concrete road construction.

Table 2. Physical and chemical properties on National Thermal Power Corporation (NTPC), Korba fly ash.

Physical Properties	
Fineness cm2/kg	3000
Lime reactivity, MPa	5.2
Chemical Properties	
Sio2	56
Al203	30
Fe203	6.5
CaO	1.2
MgO	1
K2O+Na2O	1.1
Insoluble residue	90
Loss on Ignition	0.5

Table 3. HVFA Concrete Mix proporation, per m^3

Material	Quantity
POC kg	225
Processed fly ash, kg	225
Total cementitious material, kg	450
Coarse aggregales, kg	1289
Fine Aggregates, kg	480
w/cm ratio	0.4

Table 4. Average compressive strenght of HVFA concrete

Age	Average compressive strenght (MPa)
1 day	7.8
3 days	16.7
7 days	25.8
28 days	38.3

Figure 1. Six years old and still strong in harmony with the surrounding evironment

Figure 2. Absence of shrinkage cracks

Figure 3. Absence of thermal cracks

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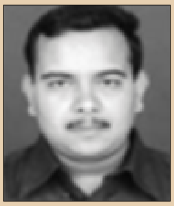
Anurag Sullerey



Mr. Anurag Sullerey received his B.E. in Civil Engineering from Government Engineering College, Jabalpur and MBA from Indira Gandhi National Open University Delhi. He is Manager at Ambuja Cements Ltd., Raipur, looking after Customer Support Group of Chhattisgarh. His experience includes concrete technology, sustainable construction, Quality Assurance, HVFA roads and training in the concrete technology

An Attempt to Create a Magic Well & Low Cost All Weather Drain

Dhiman Paul

1. Introduction

In our daily life we cherish our life by using three basic gifts from our nature which are Land, water and air. But each and every day we are polluting these three basic needs. We have to take the initiative to pretend the occurrence of pollution. With increasing population, need for ground water increases drastically. Greater volume of suction of water depletes under-ground water table. On the other hand, the used water flows through concrete drains which don't allow water to percolate in soil and recharge the under-ground water table moreover the contaminations of stagnant water and decomposed waste of drain deteriorate the quality of the water. In this project we are trying to recharge local the ground water table with lesser contaminated water.

2. Construction procedure

Tube well Platform: 75 mm thick precast RCC slab.

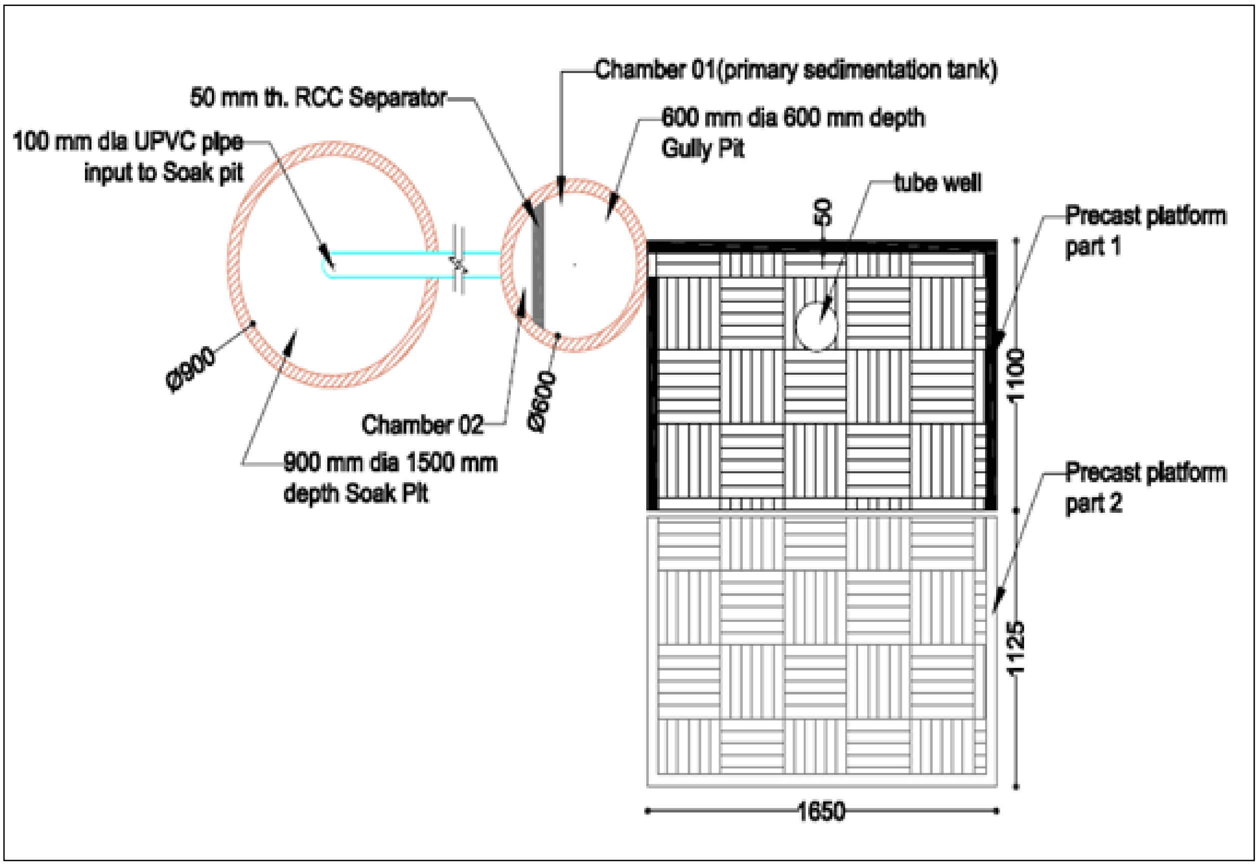
Gully Pit: 500 mm depth and 600 mm dia pit made with precast RCC ring rested on a bottom RCC slab.

Separator: 50mm thick precast RCC slab having a dimension of 450 mm X 300 mm to be fitted vertically inside the gully pit as a partition.

Drain: It may be masonry or RCC drain depending upon bends or distance of soak pit and gully pit. In this case we used 150mm dia UPVC pipe.

Soak pit: 1500 mm depth and 900 mm dia pit made with precast RCC ring covered with RCC slab.

3. Final arrangement:



4. Conclusion:

For his innovative, eco-friendly construction his Gram Panchyat got trophy for "Most Innovative Gram Panchyat " from Block Development Officer of Barrack pore-II Block of 24 Parganas(N), W.B.

Low Cost All-Weather Drain

Abstract
Rural to urban migration of population is a Universal phenomenon. People from rural are migrated to urban areas for socio-economic gains. Due to lack of affordable space in urban area, good number of immigrating population chooses low cost land in peripheral rural areas. Agricultural land in the peripheral region of Municipalities feels most of the pressure due to its easy availability and low cost. Due to huge demand, erratic and most unplanned settlements are cropping up in rural areas with near Municipalities. Rampant earth filling & levelling for need of these settlements ignores and drastically changes the natural gradient of rural land. Due to lack of resource with village level administration, providing the basic amenities like roads, drinking water and proper drainage systems settlement becomes big challenges.

1. Introduction:

- General

  Challenges faced by Gram Panchayat for providing drinking water facilities:-

  Falling water table: With increasing population, need for ground water increases drastically. Greater volume of suction of water depletes under-ground water table. On the other hand, the used water flows through concrete drains which don't allow water to percolate in soil and recharge the under-ground water table.

  Cost cutting: Gram Panchayats lack enough recourse for laying all-weather drains along all the roads in settlement. Thus cost-cutting becomes another big challenge.

  Maintenance Cost: If a part of the brick-paved conventional cemented drain is damaged by any chance, the whole length of drain is required to be re-constructed for maintaining gradient. That drains of good amount of money.

- Putulia GP of Barrackpore-II Development Block (WB) proposes concept of a low-cost method of construction of drain which is:-

  ► All-weather network of drainage
  ► Provides durability to the road flank
  ► Allows drain water to percolate into soil
  ► Easily reparable

2. Construction procedure:

- **Step 1**

  ► We have to prepare a base with the inside shape of the proposed drain, the base may be constructed by earth, bricks, concrete of metal sheet.

- **Step 2**

  ► A cage of 6 mm tor steel provided as reinforcement for the folded plat of the drain.

- **Step 3**
  - To ensure further cost - cutting, six block bricks would be used tomake the slab compact and durable, yet porous.

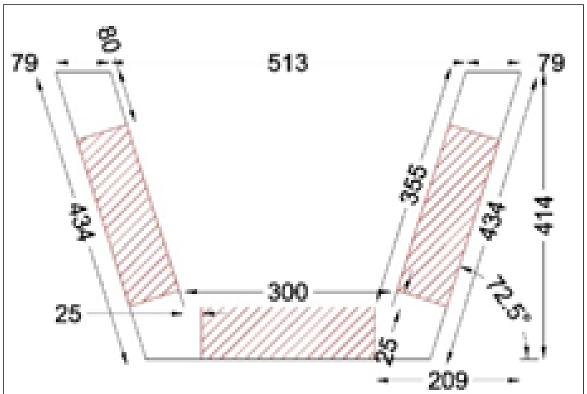
- **Step 4**
  - Providing side shuttering arrangement for male-female

- **Step 5**
  - 75mm thick RCC folded slab casting (having ratio Cement: Sand: 12mm down stone chips:: 1 : 1.5: 3 proportion

- **Step 6**
  - After one day remove from base and emerged into water for seven days for curing.

3. Physical dimension of drain:

Base wide : 300 mm
Top wide : 513 mm
Inner depth : 340 mm
Wall thickness : 75 mm
Cross section : 0.138 Sqm.
Side Inclination : 72.50



CROSS SECTION OF DRAIN

4. Advantages of the low cost trapezoidal open channel drain:

- Low cost of construction, it require only 25% of cost require for brick work drain with similar capacity.
- Low maintenance cost, ease of repair as the affected part can be replaced easily because it is divided into similar parts.
- Due to porous bed and wall the water can percolate into soil and reach to ground water layer after several natural filtrations.
- Easy to clean as water in the drain remain low.

- In rainy season water can flow through it smoothly as well as infiltrate through it so discharge time will be low in heavy rain.

5. Summary & Conclusion:

There would be no cement polish over the slab to ensure that its porosity is not removed. Each slab would be 1.5' in length. Thus the drain would be constructed laying consecutive slabs in a row. Before laying these slabs, the surface soil would have to be cut as per size & shape of the lower side of the slab. The soil surfaces have to be neatly dressed to ensure that there is no void under the slab, when laid. The drain may be effective for agricultural field channel.

Er. Dhiman Paul

Dhiman Paul has completed his M. Tech in Structural Engineering. Presently he is working with Patulia Gram Panchayat, Barrackpore, West Bengal. He is well-known person for his creative work and Innovative thinking.

Ambuja Technical Conference "A Step Towards Building Durable Structure"

Ambuja knowledge Centre Aurangabad in Association with AICA, ACE(P), ISSE & IIA Aurangabad has organized one Day Conference at Hotel Ajanta Ambassador, Aurangabad.

The Theme is " A Step Towards Building Durable Structures"

- Around 119 nominations were received.102 were present
- In this conference all four Association are came under one Platform.
- They defined & discussed development in construction Sector in Marathawada.
- They have deliberated on common solutions for building durable.
- This conference could able encouraging local construction Professionals to enhance construction quality by working together.

Seven well-known Speakers have delivered Technical lectures on durability of Concrete.

Zonal Head (Technical) Prashant Sutone has focused on Objective of Conference is to spread knowledge on Durabilty. He asked to share the Case study / good construction practices with Construction Professionals.

Er. N G Karkhane explained about the Structural audit of buildings and durability of concrete.

Dr. M. Nadeem explained about the high rise buildings and requirement of high rise building design.

Ar. Rajan Nadkarni expalained the past and future of architecture with engineering and technology. Dr. M. G. Shaikh explained the Durability aspects as per IS 456:2000.

Er. Karim Pathan explained about the Ultra Durable concrete and its design. It helps to get the concrete of more than 100 years of life.

Er. C. R. Palwankar explained about the form finish concrete and shared the very good case study of Form Finished concrete at global school of Aurangabad.

In this conference all four Association come on single Platform of Ambuja Knowledge Center Aurangabad. They have defined & discussed development in construction Sector in Marathawada. They have deliberated on common solutions for building durable structures.

102 construction Professional which includes Architects, Engineers, Structural Designers were present for full Day conference. This conference encouraged local construction Professionals to enhance construction quality by working together. Also this conference motivated to all Architects and engineers for skill up gradation with new techniques and the strong support of Ambuja Knowledge Center, Aurangabad.
Series of Technical Lectures – South Terminals

Series of Technical Lectures – South Terminals

- Series of Technical Lectures by Dr. N V Nayak were arranged at Cochin and Manglore. At Cochin, it was arranged with

Ambuja Technical Conference held

टिकाऊ बांधकामासंबंधी अभियंत्यांना परिषदेत मार्गदर्शन

ICI and at Manglore, it was arranged with local Association of Civil Engineers, at our AKC.

- At Cochin 168 and at Manglore 56 professionals were attended this lecture series
- Group discussion were also carried out with senior professionals
- Participants appreciated content of presentation

Interaction centre inauguration Karimnagar

- Interaction centre at Karimnagar was inaugurated on 31 January '17.
- We had a inauguration of the same in presence of dealers and engineers.
- It was followed by lecture of Dr. N V Nayak. It was attended by 122 professionals.
- They came from 100 km distance also.
- Feedbacks were excellent.

Answers of Quiz in ATJ - 3

Quiz: a) Fill in the blank

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

- There are 8 words related to construction.
- Mark all the 8 words and take photo.
- The photo is to be sent to us on E mail id ambuja.technicaljournal@ambujacement.com to be eligible for exciting prizes.

F	V	C	G	E	T	Z	T	N	Z
W	Y	L	I	M	E	C	O	E	K
S	K	V	Z	H	N	I	R	R	L
U	H	B	N	G	S	A	T	U	I
O	C	E	L	N	I	R	I	X	R
I	J	K	A	A	L	H	O	E	Z
V	E	P	Y	R	E	A	N	L	E
R	X	E	U	G	I	T	A	F	Q
E	W	T	V	F	L	N	L	E	M
P	W	C	V	B	Z	O	G	I	E

ANSWERS

1 (a) Higher
2 (b) Economy
3 (d) All of the above
4 (d) Bending moment, shear and torsion

Word Search

Expansion	Fatigue
Flexure	Lime
Pervious	Shearing
Tensile	Tortional

Correct answered by: Mr. Tapesh M. Sharma, Mr. Sanjay Mundra, Mr. Siddharth Jain, Mr. Shushilkumar

ATJ - 4 Quiz Corner

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

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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