RMC
TECH BEAT

Inside

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Forum

Cracking in Concrete: Not Necessarily a "Defect"!

If the complaints received by a ready-mixed concrete producer are analysed, it would be revealed that an overwhelming majority of complaints pertains to cracking in concrete. If these complaints are further scrutinized closely a clear tendency is discernible amongst specifiers to treat all types of cracks – whether major or minor - as "defects". There is hardly any attempt on the part of specifiers to carry out the root cause analysis and understand the *raison d'etre* behind the cracking phenomenon. It has almost become a 'fashion' to put the blame for cracking squarely on the shoulders of ready-mixed concrete producers. There are occasions when some specifiers and consultants even go to the extent of ordering demolition of the newly-laid cracked concrete and the RMC producer is asked to bear the cost of demolition and relaying of fresh concrete!

It may not be an exaggeration to state that RMC producers are currently victims of two blatant myths – all cracks, whether minor or major, are serious defects in concrete and that the RMC producer is solely responsible for them.

Let's initially understand certain basics. Concrete has an inherent tendency to crack. Crack-free concrete is a myth! Even in freshly-laid concrete, there are micro-cracks. Fortunately, these are extremely thin, which are not visible and are not interconnected. Volume change phenomenon in concrete is one of the major causes of cracking. Just

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Company News

Elitecrete™ Applications Graining Ground

It is estimated that in advanced countries energy consumption in residential and commercial buildings account for nearly 40% of the total energy used. Although no similar Indian estimate is available, the picture in energy consumption in big urban centers in India may not be very much different.

From sustainability considerations, there is an urgent need to reduce energy consumption in buildings and one of the effective ways to achieve this is to use energy-efficient construction material, possessing high thermal insulation properties. Considering this need, RMC Readymix (India) has developed an innovative product known as Elitecrete™.

It is non-structural lightweight concrete having densities ranging from 800-1800 kg/m^3. Elitecrete™ not only reduces the dead load on the building but also provides good thermal insulation. At a time when energy costs are skyrocketing, the use of Elitecrete™ can be immensely beneficial to owners and users, especially in locations subjected to extreme temperatures. And of course, the benefits accruing from the reduction in the deadweight will certainly be appreciated by the structural designer and architect. In addition, Elitecrete™ has an excellent fire and sound resistance and the free flowing characteristics of the product enable faster construction.

Elitecrete™ in NCR Region

Elitecrete™ is being used for applications at various locations across India. In the NCR Haryana region, this product was used on the roof slab of the showrooms of big commercial complexes belonging to automobile giants.

In view of its lightweight nature, Elitecrete™ is preferred by consultants as a filler in the sunken portions of structural elements. One large application for sunken portion of slabs is happening in Gurgaon area. The density requirement for this project is 1000 kg/m^3.

RMC Readymix (India) has also supplied Elitecrete™ with a density of 1200 kg/m^3 for a large corporate office, to be used over roof slab to reduce dead load over foundations and also to take benefit of its insulating properties.

The production and supply of Elitecrete™ require a higher degree of quality control and regular monitoring of the concrete dispatches from the batching plant. This is achieved by RMC Readymix (India) through effective

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Around the World

PCA Turns 100

The Portland Cement Association (PCA) is currently celebrating its centennial year. During the last 100 years, PCA has become widely recognized as the authority on the technology, economics, and applications of cement and concrete.

The anniversary marks an occasion to not only celebrate the association, but also to assess where the industry has come and where it is heading into the next century. Many of the roads and buildings promoted a century ago not only still exist, but remain in active use. This is not just a testament to the resiliency of concrete, but also its role as a building block of society. Without concrete our homes, roads, schools, and cities would not exist as they are today.

The year will be filled with many events. For more details, log on to www.cement.org.

(*Source :* PCA News)

Needed Resilient Road Network for Climate Change Adaption

The European Concrete Pavement Association (EUPAVE) in its recent Position Paper has appealed to the European Commission and road authorities to build resilient and durable transport infrastructure that will be needed to adapt to the changing climate.

Two main consequences of climate change that will affect roads are increases in temperature and precipitation, which will increase flooding, erosion of embankments and foundations and loss of pavement integrity. According to European Environment Agency, the increase in temperature in hot days during summer will lead to softening and rutting of flexible pavements. Further, increased temperature may lead to intensification of freeze-thaw cycles, which may accelerate the pavement deterioration. In addition, the increased frequency of storm surges and flooding will affect granular subbases and subgrades, leading to damage of pavements.

Compared to asphalt pavements, concrete pavements are long-lasting and are built to withstand changes in temperature or moisture. Concrete stiffness remains constant in the range of ambient temperatures, not suffering softening or rutting. In fact, the surface of concrete is robust and it keeps its properties (micro-texture, macro-texture, roughness and skid resistance) over time, independently of climate effects.

Considering the other advantages of concrete pavements such as reduced life cycle cost, reduced maintenance, long-term durability, etc., these pavement provide an ideal solution to combat the effects of climate change.

EUPAVE has called upon the European Commission and Member States to make long-term thinking a mandatory component in public tendering for road building and consider the resilience of the entire road network in Member State adaptation plans as part of the EU Adaptation Strategy.

(*Source* : www.eupave.eu)

Readers' Forum

Dear Sir,

Thanks for sharing the *RMC TechBeat* (Vol. 2, No 1). I request you to please keep sharing *TechBeat* every quarterly.

The feature titled *"Estimating Peak Temperature in Mass Concrete"* is quite informative. I agree that a separate nomogram suiting to Indian conditions will have to be developed. However, one would require large field data to develop this. We need to look into this aspect.

Typically, Indian specifications do not underline the necessity of monitoring the temperatures of concrete on a routine basis - whether it is surface temperature or core temperature of the concrete sections. Even in our company we generally specify the temperature limits for very critical structures (like mass concretes designed to take dynamic loads).

Keeping in view the recent development on durability of concretes - shift from specifying "prescriptive to performance based specifications", we certainly would have to look into mass concretes in a different perspective with respect to the impact of temperature on overall durability. This is all the more significant when we are looking for durability aspects considering service life of over 50 or 100 years.

I feel that there is a need to standardise the definition of mass concretes vis-à-vis other concretes, duly considering not only the dimensions of the pours but also the temperature development aspects during the service life of the structure. It is also important to consider specifying the limiting temperatures for the mass concrete pours with suitable performance criteria for ensuring durability. Such standardisation needs to be enforced on pan India basis.

Regards
K V Jagadish
Tata Consulting Engineers

Concrete Innovations & Trends

Monitoring Crucial Temperature Parameters during Thermocrete® Application

Ever since Thermocrete® was launched by RMC Readymix (India), the Company has executed a number of successful applications of this special product. Thermocrete® has been used in massive raft foundations, deep beams and in some other applications. In most of these applications, this special product was used basically to control the heat of hydration and to avoid the possible risk of early-age thermal cracking.

For concretes used in mass foundations and deep lifts, following three temperature parameters become crucial:

- Temperature at placement
- Peak temperature reached within concrete mass,and
- Temperature gradient.

Codes and standards generally do not specify any particular value of temperature at placement; they however advise that the temperature at placement should be as low as practicable. As regards second criteria, the possibility of the formation of a phenomenon known as Delayed Ettringite Formation (DEF) limits the peak temperature. Excessive temperature generated within the body of the mass concrete prevents the normal formation of ettringite, which is then formed later after the concrete has hardened. This later-age formation of ettringite can lead to expansion and cracking of concrete. Therefore with a view to prevent the formation of DEF, the peak temperature in mass concrete is usually limited to 70°C, when no preventive measures are taken or up to 85°C when certain percentage of supplementary cementitious materials like fly ash, blast-furnace slag, silica fume, etc. are used and/or low-heat Portland cement is used in place of ordinary Portland cement. It is also observed that the formation of temperature gradient in excess of 20°C within the body of the mass concrete may lead to thermal cracking of the concrete. Hence, precautions are taken to ensure that the maximum temperature gradient does not exceed 20°C.

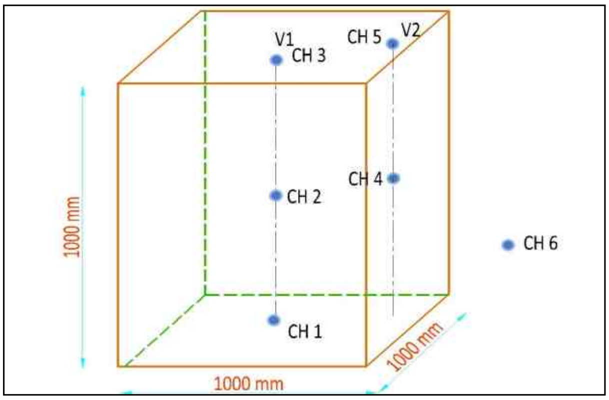

Fig 1 Mock up trial arrangement showing 1m x1m x1m concrete block and the location of probes

During construction, while it is easy to measure the temperature at the time of placement, special arrangements of temperature monitoring are essential to assess the other two parameters, namely, the peak temperature reached and the maximum temperature gradient observed during the stiffening, hardening and hardened phases of concrete. Temperature monitoring can be done by inserting probes into concrete before casting. The probes are connected to a central data logger system which continuously monitors the temperature profile within the concrete.

For developing a tailor-made mix of Thermocrete®, RMC Readymix(India) recently conducted a mock up trial in Mumbai. The mock up trial was done by casting a 1m x 1m x 1m block wherein three Resistance Temperature Detectors (RTDs) were embedded in a vertical rod placed in the concrete. The three RTDs were spaced equally - one each at top, middle and bottom (see Fig 1). One RTD was kept in the open to monitor the ambient temperature. Temperature development within the block was recorded for 200 hours. The temperature monitoring data showed that for the Thermocrete® mix the peak temperature rose to a maximum value of 60°C and the temperature gradient was lower than the limiting value of 20°C. This can be seen from the plots in Fig 2 (a) and (b). With the successful completion of the mock up trial, the Mumbai team of RMC Readymix (India) was confident of fulfilling the specific needs of the customers.

In one of the recent applications of Thermocrete® in Mumbai, actual monitoring of the temperature regime was done with the help of sensors installed in the mass concrete. The permissible values of peak temperature and the temperature

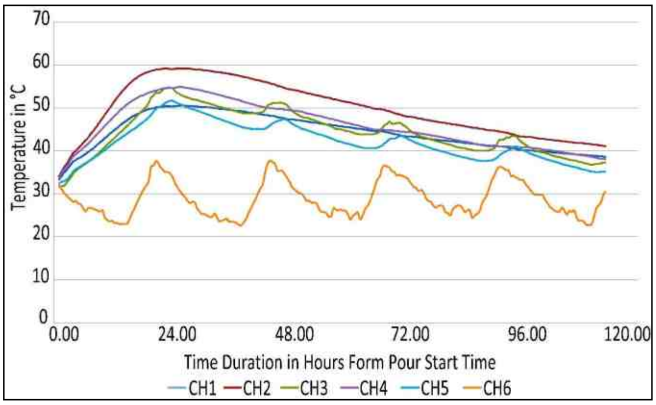

Fig 2 (a) Temperature monitoring curves during mock-up trial

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Concrete Innovations & Trends

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gradient as specified by the client were successfully achieved.

The application of Thermocrete® was for mass concrete of a transfer girder having a depth of around 1.2m. The total concrete quantity in the massive girder was around 2500 m^3. The specified 28-day compressive strength was 60 MPa. In addition, the client had specified the following three temperature-related parameters:

- Temperature at pour = 30°C
- Peak temperature in concrete: < 75°C
- Temperature gradient: not to exceed 20°C.

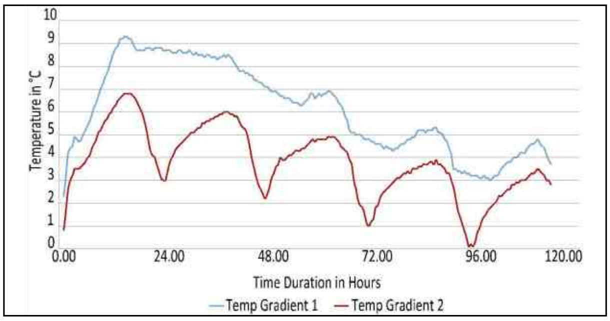

Fig 2 (b) Temperature gradient curves during mock up trial

A number of laboratory trials were conducted to arrive at the optimized mix proportions which satisfied both the compressive strength criteria and the temperature profile requirements. The travel time from the Company's plant to the site was around 30-45 minutes.

With the use of chilled water it was possible to achieve the temperature of the fresh concrete of around 24-25°C at the plant and around 28-30°C at the pour site, Fig 3.

Fig 3 Temperature at pour was well within the specified value of 30°C

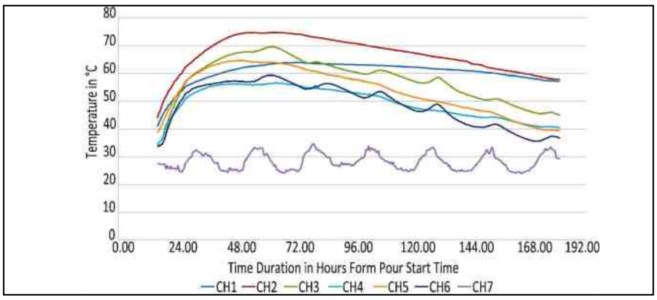

Fig 4 (a) Temperature monitoring curves

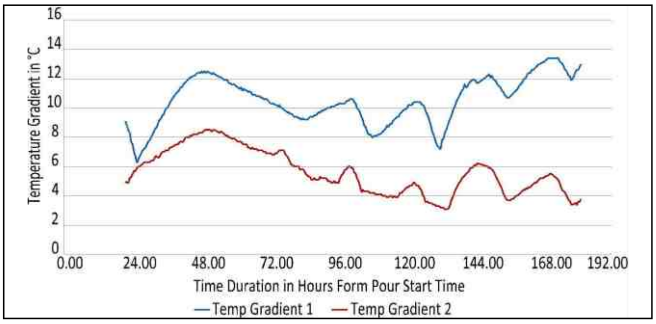

Fig 4 (b)Temperature gradient curves during field application

The temperature development profile in each big pour was monitored with the help of embedded Resistance Temperature Detectors (RTDs) located in vertical rods which were placed in the concrete mass. A total of six RTDs were installed - three each in one vertical rod. One RTD was kept in the open to monitor the ambient temperature. The RTDs were numbered and tied to the reinforcement. The cable connected to the RTDs was protected from damage during vibration or other movement during concreting. The sensor output from RTDs was fed into a digital data logger and recorder. The actual data generated for one of the pours is included in Fig 4 (a) and (b).

It was observed that the maximum temperature reached during the actual pour was 73°C (Fig 5 (a)) as against the limiting specified value of 75°C and the temperature gradient was well within the specified limit of 20°C (Fig 4 (b)).

For protecting the concrete, the contractor had kept formwork in position for a longer period than essential and the top portion was covered with a cost-effective insulation system, comprising of a combination of plastic sheets, expanded polystyrene sheets and wooden planks.

The RMC Readymix (India) team is now equipped to offer the temperature monitoring services along with the supply of Thermocrete®.

Forum

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Cracking in Concrete: Not Necessarily a "Defect"!

imagine - if all portions within a concrete element are free to move as the concrete expands or contracts due to volume changes, there will be no cracking. In actual practice this is not possible. This is because there are restraints to these movements - from within the concrete (for example reinforcement) and outside (for example formwork). When the stresses created by the restraints exceed the capability of the concrete to withstand them, cracking occurs.

Volume changes in concrete manifest as shrinkage, which in simple term means contraction of concrete upon loss of water. Neville, Acker and Aitcin[1] report that there are five types of shrinkages – autogeneous, plastic, drying, thermal and carbonation shrinkage. Although the mechanisms of these shrinkages are different, they all are the result of the physical, chemical and thermodynamic changes occurring during hydration or hardened state. Concrete shrinkage is never a single mechanism; it is a combination of different types - and more importantly, different shrinkages are additive in nature. If design and construction practices do not take account the effects of different shrinkages, there would be a possibility of cracking.

Besides volume changes in concrete, there are many other factors which are responsible for cracking. These include, for example, form work / subgrade movement, design errors, over loading, etc. A technical report from Concrete Society [2], U.K., includes a family tree of cracking, which is divided into two principle categories - cracks appearing before hardening and after hardening (see Fig 1).

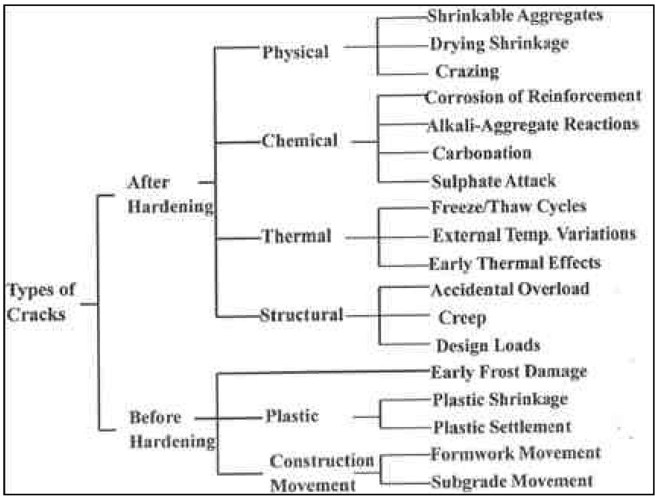

Fig 1 The family of cracking tree[2]

It is obvious from the cracking tree shown in Fig 1 that numerous factors are responsible for the phenomenon. Therefore the first challenge that anyone faces is to ascertain the cause(s) of cracking and determine its source(s) in a reliable manner. Without going into this exercise it would be inappropriate and unfair to attribute the source of cracking squarely on the ready-mixed concrete producer.

In normal-strength concrete, plastic and drying shrinkages are quite common. While plastic shrinkage cracks appear before the initial set, drying shrinkage cracks occur at a later age - may be after a week, fortnight or even a month. A number of measures can be taken to mitigate the adverse effects of these shrinkages. One of the most cost-effective and simple solutions involves protection of the concrete from high ambient temperature and wind in the initial period by covering the exposed surfaces of concrete just after placement and start curing early and continue the same for adequate period. These measures, which fall under the jurisdiction of the contractor, are quite often not implemented properly in actual practice, leading to cracking of concrete. It is here that attempts are made to blame the ready-mixed concrete producer for cracks, even when the fault does not lie with him.

It is well known that concrete is strong in compression and weak in tension. In reinforced concrete, the structural designer provides reinforcement to cater to the tensile forces and moments generated in the concrete element. However, before reinforcing steel becomes effective and starts carrying the load, concrete needs to crack! Thus, structural concrete is required to crack so that the reinforcing steel becomes effectively engaged. One needs to consider such minor cracking as normal.

In this context, it would be appropriate to quote American Concrete Institute's report ACI 302.1R-04, "Guide for Concrete Floor and Slab Construction," which in its Foreword states,

> "...Even with the best slab designs and construction it is unrealistic to expect crack-free and curl-free floors. Every owner should be advised by the designer and contractor that it is normal to expect some cracking and curling on every project. This does not necessarily reflect adversely on the adequacy of floor's design or quality of construction".

The real question is what type and extent of cracking should be considered as normal? Codes and standards in different countries provide formulae to evaluate the crack width and also specify limiting values of crack width. For example, IS 456 specifies the following:

> "The surface width of the cracks should not, in general,

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> exceed 0.3 mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel nor upon the durability of the structures. In members where cracking in the tensile zone is harmful ... an upper limit of 0.2 mm is suggested for the maximum width of cracks. For particularly aggressive environment, such as the 'severe' category in Table 3 (of IS 456), the assessed surface width of cracks should not in general, exceed 0.1 mm."

However, it needs to be understood that the limiting values of crack widths are specified for structural design purpose to provide proper detailing, such as provision of minimum reinforcement and proper selection of bar diameters, bar spacing, and reduction of restraint. The ACI 224.1R-014, while providing the limiting values of crack widths states that

> "It should be expected that a portion of the cracks in the structure will exceed these (crack width) values. With time, a significant portion can exceed these values. These (crack width values) are general guidelines for design to be used in conjunction with sound engineering judgement."

Thus, some amount of minor cracking is to be expected in any concrete structure. It is the end use of concrete application which should determine the acceptability or non-acceptability of cracking. For instant, a through-and-through crack in water-contact structure should be unacceptable, as it will cause leakage. However, minor cracking in slabs, beams, columns, etc. should be considered acceptable.

Cracking in concrete can be considered as "defect" only when it leads to reduction in strength, stiffness and durability of the structure to an unacceptable level or if the functioning of the structure is seriously impaired. Cracking can also be objectionable where the size and spacing of the cracks compromise the strength, stability, serviceability or appearance of the structure.

However, in certain other cases the design requirements may be so demanding and site conditions would be so challenging that it may not be possible to control cracking in spite of taking the usual mitigation efforts. Realising this ACI 207.2R5 states,

> "Design strength requirements, placing restrictions, and the environment itself are sometimes so severe that it is impractical to mitigate cracking solely by measures to minimize volume change."

ACI 224R-01 on "Control of Cracking in Concrete Structures" provides information "to assist in the development of practical and effective crack-control programs for concrete structures". There is an urgent need to evolve such guidance document in India. Once the Indian version of such measures are developed and specified by the designer and contractors, it will become easy for the ready-mixed concrete producer to adhere to the specified norms and the owner to verify the performance accordingly. If the ready-mixed concrete producer performs in accordence with the laid-down plans and specifications, he should not be held responsible for the defects.

The inevitability of cracking in concrete has been highlighted in internationally-accepted literature. It is for the engineer-in-charge to make a sound engineering judgement to decide if the cracks are acceptable or are defects.

Of course, the customers and specifiers have the freedom to specify additional crack-preventive measures such as use of synethetic/steel fibres, use of shrinkage-reducing admixtures, etc. However, all such measures involve extra cost.

The above discussion can be summerized by stating the following:

- Minor cracking is inevitable in concrete elements.
- Cracks *per se* should not be considered as 'defects' and ready-mixed concrete producer should not be made a scapegoat for the same.
- It is suggested that for mitigating cracking in concrete well-designed measures including concrete mix proportions and verification of the same, concrete protection procedures and curing regime should be developed in consultation with all stakeholders and specified in all contracts. Once it is verified that RMC producer has followed the specified norms, he need not be blamed for the occurrence of cracks.
- Only those cracks where it can be conclusively proved that the cracks may lead to loss of load carrying capacity or durability problems or seriously mar architechtural appearance should be considered as defects and repaired.

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1. Aitcin, P. C., Neville, A. M., Acker, P. Intergrated view of shrinkage deformation, Concrete International, September 1997, pp.35-41.
2. Non-structural cracks in Concrete, Concrete Society Technical Report 22, 3rd Edition, Concrete Society, UK.
3. ACI 360R-10, Guide to design of slabs on ground, Reported by ACI Committee 360, American Concrete Institute, USA.
4. ACI 224.1R-2001, Control of Cracking of Concrete Structures, Reported by ACI Committee 224, American Concrete Institute, USA.
5. "Cracks in Slabs on Ground", ASCC Position Statement # 29, American Society of Concrete Contractors, USA.

Company News

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production control and by testing the product for wet density, flow, and yield at a regular interval.

Elitecrete™ at Kochin

Elitecrete™ was recently used as filler in the sunken portion of the main slab and toilets at the Kochin International Airport. Here, the requirement was to cover the services such as water mains, electrical conduits, etc. The thickness of the filler was around 350 mm over the main slab and 250 mm over the toilet. It is proposed to provide a thin layer of waterproofing screed over Elitecrete™. On top of the screed, it is proposed to lay skid-resistant tiles.

The client specified a density of 1200 kg/m^3. Elitecrete™ having the desired density was supplied by RMC Readymix (India) to the satisfaction of the client.

Elitecrete™ being poured in the sunken portion

Xpresscretre™ for Tunnel Form Construction

Rapid construction of residential housing has become a necessity. Tunnel form construction is one of the suitable techniques of rapid construction and its use is growing in India. In typical tunnel form construction, the forms are made of robust structural steel plates and cut-outs for windows, doors, etc. are left at pre-determined locations. All services are provided within the walls.

Concrete is poured in three wall forms and the top slab in one single pour. The surface finish of construction is so good that there is no need for any plastering. The tunnel form construction combines a number of benefits such as higher speed of construction, quality, accuracy and overall economy.

The speed of construction using tunnel form is dependent upon the cycle time which in turn depends upon how fast the formwork can be removed. Faster removal of forms can be achieved with the use of high-early strength concrete.

Knowing that RMC Readymix (India) has developed a special product names as Xpresscrete™, a client from Bangalore approached the Company to develop a tailor-made concrete mix which is free flowing and will be able to achieve a compressive strength of 12 MPa in 12 hours and 15 MPa in 15 hours. RMC Readymix (India) team in Bangalore took up the challenge and developed the tailor-made Xpresscrete™ to the satisfaction of the client.

Xpresscrete™ is now being supplied to the project and the client is in a position to remove the formwork as originally planned. The client is happy to witness that there is no segregation, honeycombing, cracks in the concrete. The finished surface has been excellent.

Xpresscrete™ for tunnel form application – good concrete finish eliminates the need of plaster

Students visit RMC plant

Around 75 students from Sardar Patel College of Engineering, Andheri, Mumbai, visited the Ghatkopar Plant and the central laboratory recently. The students were accompanied with two faculty members. The visitors were impressed with the available lab facilities and a variety of provisions in modern state-of-the art plant.

Mail Box

Q. : We are one of the progressive builders from a three-tier city in north India. We have recently launched a housing scheme involving construction of residential and commercial buildings and the construction work is presently in progress. We have started using concrete from a local commercial ready-mixed concrete plant but are not happy with the quality of the concrete and service. In particular, we are facing problems of large variations in slump at site leading to segregation and honeycombing. The in-charge of the local commercial ready-mixed concrete producer measures slump and takes cubes at his plant itself. We understand that this is not a correct procedure and that we need to sample concrete at site for measuring slump and filling the cubes. Our project also requires concrete to be pumped up to 20 storeys. Should we therefore not check slump of concrete at the pump discharge location at different floors? Since your Company is one of the leading RMC producers in the country and possesses long experience in this field, may we request you to advise us regarding the correct location of sampling?

A. We are thankful to you for referring your problem to us. Although we do not currently have a presence in your city, as a responsible ready-mixed concrete producer we consider it to be our duty to respond to your queries.

At the outset, we would like to point out that the production and supply of ready-mixed concrete are governed by the provisions in the Bureau of Indian Standards' specifications i.e. IS 4926. The standard clearly states that the sampling of concrete should necessarily be done at site and not at the RMC plant. The IS Standard also provides detailed sampling procedure in its Annex C. It is our observation that on many occasions sampling is not done properly. The crucial steps in sampling as laid in Is 4926 are reproduced here:

- First 1/3rd and last one m^3 portion of concrete from transit mixer should be ignored in sampling.
- Four incremental samples should be taken from the middle portion.
- Through mixing of composite samples should be done on a mixing tray.
- Slump cone and cubes should be filled in accordance with the given procedure from the mixed concrete from the tray.

As regards your second question on taking samples at the discharge end of the pump, we would like to clarify that this is not practicable and hence not practiced in the industry. The IS 4926 clarifies this by stating, "..point and time of sampling shall be at discharge from the producer's delivery vehicle or from mixer to the site or when delivered into the purchaser's vehicle". The IS standard nowhere mentions that the sample should be taken at the delivery end of the pump. ASTM C 94, which happens to be one of the oldest standards on ready-mixed concrete, also does not specifically mentions that the sample should be taken at the delivery end of the pump.

There will certainly be a reduction in the workability after concrete gets pumped. However, it is difficult to estimate such reduction as it depends upon a host of factors such as type of mix ingredients and their proportions, type and amount of chemical admixture, pump pressure, pipeline length and diameter, number of bends, etc. Some of these factors can significantly change while placing the same load of concrete. In view of the uncertainties involved in measuring slump at the point of placement, it is always a good practice to measure it at the point of discharge from the transit mixer.

Persons and agencies involved in pumping operations do possess necessary experience to roughly estimate the possible reduction in the slump loss after pumping. Based on this rough estimate, the contractor and/or consultant specify slightly higher values of slump at the discharge point (pump hopper), where it is easy to measure the slump.

Trust, we have provided satisfactory answers to your queries.

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