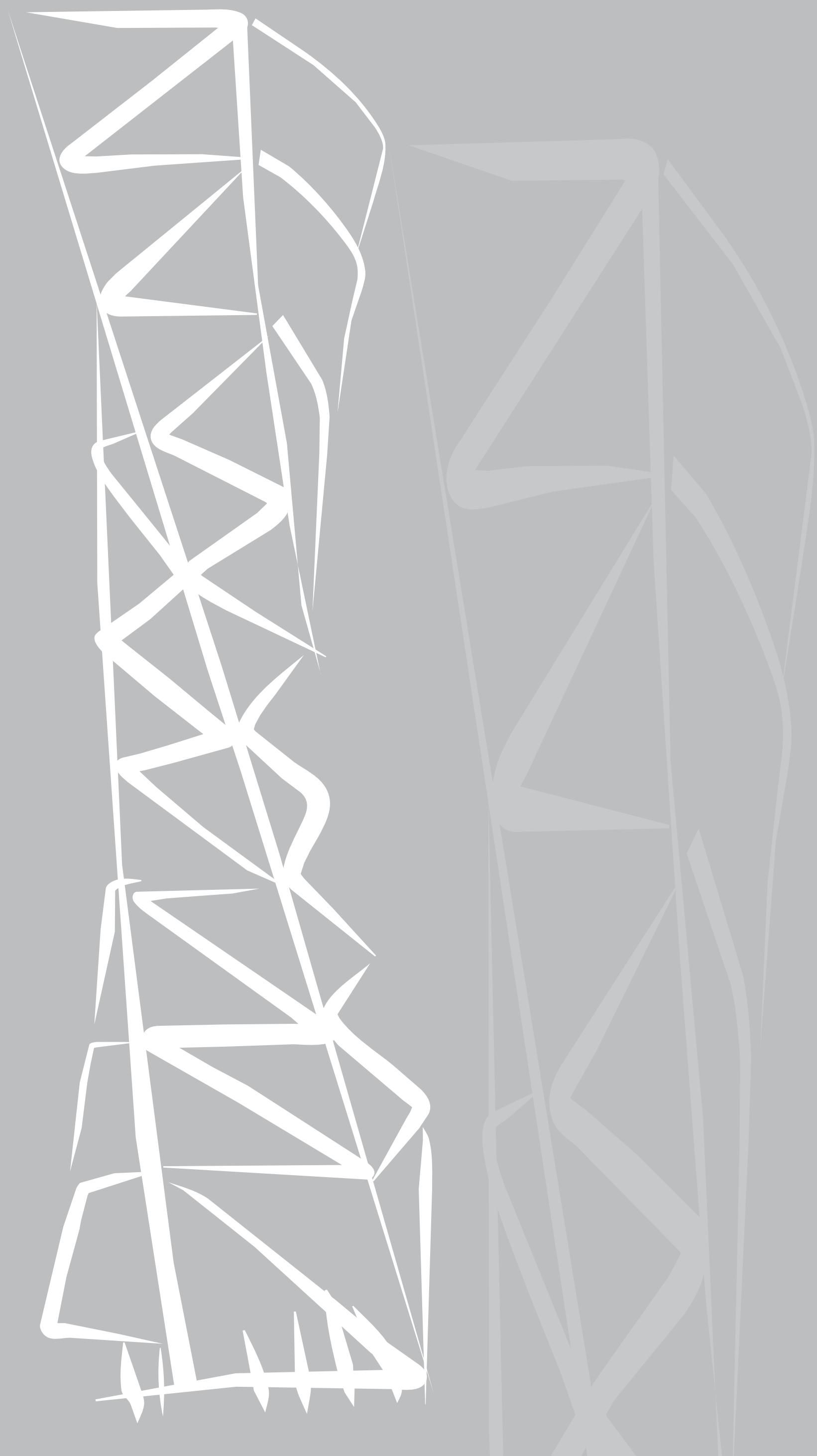
For private circulation only

Ambuja foundations
A KNOWLEDGE INITIATIVE

ATJ
Ambuja Technical Journal

Volume 3 | February 2017

ENGINEER · ARCHITECT · STRUCTURAL ENGINEER · CEMENT · SKILL

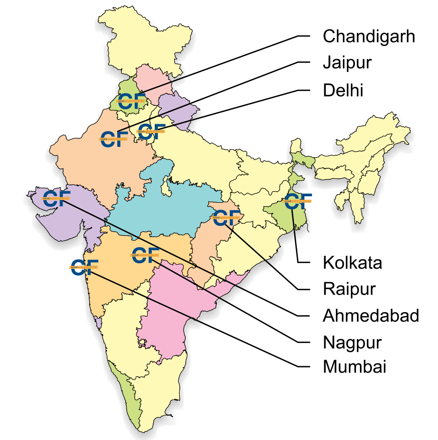


Come...Partner with us
as we build the Foundations of the Future

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

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

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



Besides, we also offer concrete mix design services for :

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

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

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

Ambuja Cement
Giant Compressive Strength

EDITORIAL

On the onset of new year, let us wish you a hapy new year, may this year bring joy, peace and happiness to you and entire family…

The objective of the journal is to bring the best practices prevailing across shared by experts, practicing professionals to improve and extend at fieldwork. The results of R&D and other technical progress have been consistently brought to the notice of the readers. This relentless dissemination of latest technical knowledge coupled with constant advocation of good engineering practices, quality control and pursuit of technological excellence would certainly benefit engineers, consultants, architects, contractors, researchers, etc.

In this issue, technical papers comprises on varied topics of the interest of many like Bubble deck slab, Effective curing solution to vertical surfaces, Bacterial concrete, SCC, UHPC, Sustainability solutions etc. followed by interesting quiz and newly introduced 'Ask the Expert Corner.

In order to further address specific queries/issues faced by field professionals, we introduced 'Ask the Expert Corner' from this issue. During the filed working, its obvious that many of us come across queries, issue or need solution on many technical aspects. In that case, any of you need to share with us, the query will be referred to the panel of experts and their expert comments / solutions will appear in subsequent publications.

Let us continue this journey of excellence with continued support from all of you..

Technical Services Team
Ambuja Cement

Index

Bacterial Concrete: An Innovative Material

S. Mandal

Abstract

Now-a-days alternative approaches in construction technology are evolving rapidly in a bid to curtail the environmental hazards and low sustainability imparted by the prevalent technologies. Use of suitable microorganisms / bacteria in concrete to improve its pore structure is now an important field of research all over the world. Many researchers have identified different microorganisms /bacteria suitable for cementitious material for strength and durability improvement by the formation of mainly calcite. The present study also deals with the application of the novel bacteria and also its protein Bioremediase in cementitious material to improve overall behavior of concrete material. This silica leaching bacteria or bacterial protein in its purified by lyophilized form when impregnated into the OPC/PPC based concrete and mortar samples, found to increase remarkably the compressive strength, flexural strength, resistance to water absorption and sulphate attack as well as self-healing attributes of the test specimens. This Bioremediase protein exhibits sustainability across a wide time and temperature barrier. These findings along with the fact that this protein does not impart any negative repercussion on human health may render it as a prospective agent in construction technology.

Keywords

Microbial protein, Concrete, Compressive Strength, Sustainability, Portland Pozzolana Cement

Introduction

General

Biologically augmentation of strength of cementious materials has beckoned the researchers around the globe in recent times. Concrete, the common place construction material all over the world is ascribed with high compressive strength but modest tensile strength. Its inadequacy of tensile strength paves way for counter balancing via the use of reinforcements (e.g. steel rebar). However, even after reinforcement, cracks surface over concrete structure as fallout of applied structural loading, shrinkage and thermal deformations, most of them are, in true sense, inevitable and expected within the context of practicality. Commonly used reinforcement agents in construction materials corrode the structure within, thus bringing down the shelf life of the structures. Occurrence of cracks cut down the load capacity and stiffness of the concrete structure by yielding passage to ions-the chief culpable of concrete deterioration. Chloride ions, oxygen and carbonating agents can pass through the cracks and end up in corroding reinforcing steel, which contributes to the extensive disintegration of concrete structure globally (Mehta, 1999). Hence, occurrence of cracks is a prevalent form of damage in concrete structures. All these lead to appreciation of manufacture and maintenance cost of concrete based structure coupled with potential of environmental hazards. In this context, concept of bio mineralization should play an important role.

Bio mineralization is a metabolic process of formation of hard structures, surfaces or scales by combining minerals with organic compounds of some specific microorganisms (Skinner and Jahren, 2003). According to Belkova (2005) metabolic activity of some specific microorganisms play a pivotal role in the transformation of many members of the periodic table. Specific microbial proteins influence the bio mineralization process either through guiding prevention or formation of mineral deposits (Boskey, 2003). This bio minerology concept has been looked into very keenly for development of new bio concrete material (Ramachandran et al., 2001; Ghosh et al., 2005), cleaning of concrete surface (DeGraef et al., 2005) and imparting microorganisms directly for inducing calcite precipitation in concrete crack (Bang et al., 2001; Rodriguez-Navarro et al., 2003). The present study furnishes a performance analysis of the novel bacterium BKH1 and its secretary bioremediase protein regarding compressive strength enhancement, tensile strength and self-healing attributes of OPC and PPC based specimens.

Growth and Culturing Bacteria

Bacteria are single cell organisms. It is a prokaryotic cell that lack of a nucleus and other membrane enclosed structure. Typically, bacteria come in three basic shapes namely, sphere, rod-like and spiral. Some bacteria do not fit any of the preceding categories but rather have spindle shapes or irregular lobbed shapes. Bacteria can be found in every environment such as in the air, food, soil and water. Many bacteria benefits human and a few may cause disease to human. Bacteria play vital role in most of the environment cycle like biogeochemical cycle, water cycle, carbon cycle, nitrogen cycle and sulfur cycle. However, there are numbers of bacteria that is not characterized and only some of the bacteria have been grown in a laboratory for specific application. Bacteria growths are characterized in three phases. The first phase is called the lag phase or rapid growth, when bacteria receive a lot of carbon sources and nutrient. The second phase of growth is the logarithm growth or exponential phase. In log phase the nutrient is metabolized until one of the nutrient deplete. The final stage of growth is the stationary phase and the nutrient is depleted. It is also needed to develop proper nutrient for the growth of a particular bacteria for practical purpose.

Bio Mineralization

Mineralization is a process that allows precipitation of chemical in mineral phase. The process of mineralization is called bio mineralization with immobilization of bacteria in concrete for chemical precipitation. In the concrete, the bacteria creates micro environment with the condition to allow carbonate precipitation in the form of calcite. Bacteria precipitation calcium carbonate resulted from metabolic activities namely, photosynthesis, sulphate reduction or urea hydrolysis. Most of the bacteria that are found in soil, sand, water or natural mineral have the ability to precipitate carbonate under desire optimum environment such as pH, temperature, nutrient, and redox potential. Each of the environment condition must remain within the tolerance range of the bacteria to sustain basis in concrete environment. It must be noted that bacteria isolated from other metabolic process may have similar performance for improving life span of concrete. Some of the bacteria that shows positive effects in cementitious material are B. pasteura Shewanella sp (Ramachandran et al) Bacillus sphaericus (Ballie, N.D.), Bacillus cohinii (Jonkers, H. M). The fundamental process in microorganisms for transforming minerals involves proteins and/or other biological macromolecules that control the nucleation and growth of the inorganic structure. The process of bio mineralization and assembly of the inorganic components into hierarchical, sophisticated structures has led to the development of a variety of approaches that mimic the recognition and nucleation capabilities found in biomolecules for inorganic materials synthesis. The implication of bio mineralization on the development of materials either at the nano- or micro-scale has stimulated significant progress in understanding the underlying biochemical processes. It is also possible to modification of pore structure of forming deposit other than calcite within the cementitious system using proper selection of bacteria. It has been identified the problems of using the bacterial cell in the practical of concrete structure. Thus the extraction of protein from the bacteria should have been explores for the practical use.

Bacteria cannot tolerate with extreme pH value. Under highly alkaline or acidic condition some bacteria cell may be hydrolyzed or enzyme denatured. The pH of the environment affects microorganism and microbial enzymes and also influence the dissociation and solubility of many molecules that indirectly influence microorganism. Bacteria have a characteristic, optimal growth temperature at which the bacteria exhibit the highest growth and reproduction rate. Considering that the temperature normally fluctuates, on a daily or seasonal basis, most of the bacteria can tolerate with this fluctuation of pH. Nutrient can be in the form of organic or inorganic compound. Some bacteria requires high organic compound whereas others grow only at low concentration. Many inorganic compounds are essential nutrients for bacteria. Some chemical forms of organic compound are as microbial nutrient or inhibitors.

Experimental Program

Bacteria and its Growth Condition

The bacterium was isolated from the crude soil samples of a hot spring at Bakreshwar, West Bengal, India. This is a facultative anaerobic and iron reducing bacterium and closely related with the Thermoanaerobactor fermicutes (Biswas et al., 2010). In sealed glass pressure vials it can be cultured anaerobically (in presence of CO2 atmosphere) (Chattopadhyay et al. 1993) in a synthetic growth medium (containing Fe(OH)3 – 0.1 M, Na2HPO4 – 0.6 g/L, KCl – 0.33 g/L, Na2CO3 – 2.5 g/L, yeast extract – 0.02% and peptone – 0.5%) at pH 8.0 and 65 oC temperature (Ghosh et al., 2005). This bacterium has been found to survive up to pH 12.0 of the growth medium; however its growth rate is slowed down at this high pH level (Biswas et al., 2010). A few proteins are secreted by this anaerobic bacterium in the growth medium during its growth. One of the secretary proteins having molecular weight of 28 kDa has shown silica-leaching property (Biswas et al., 2010) similar to marine sponge (Cha et al., 1999). The protein is named as "Bio remediase", which is non-harmful, and eco-friendly processing additive.

Purification of Bacterial Protein from Growth Medium

About 100 ml bacteria grown culture medium (6 – 8 days old) containing bacteria in the magnitude of 108 bacterial cells per ml was taken in a tube and centrifuged. The supernatant of the centrifuged culturemedium was taken in a round bottom flask and lyophilized (Freeze dryer FD-1, Rikakikai, Toshiba) to dust powder (approximately 600 mg powder obtained from 100 ml bacterium grown cultured medium). The dust powder was then dissolved in 10 ml deionized distilled water and 20 ml of ice-cold acetone was added to it and kept at 4 oC for overnight. The crude proteins thus precipitated were separated by centrifugation and lyophilized to dust crude protein powder (about 200 mg obtained from 600 mg dust powder). The crude protein was then dissolved in 2 ml of deionized sterile water and loaded on Sephadex G-100 column (100 cm ×1 cm). Fractions (1 ml each) were collected through fraction collector (Eyela DC-1000). Measuring the optical densities of the fractions at 280 nm monitored the protein containing fractions. Bio silicification activity of each column-purified protein containing fractions was performed using tetraethoxyorthosilicate (TEOS) as substrate. Those fractions showed bio silicification activity were pooled, concentrated by lyophilization and similarly eluted through the same Sephadex G-100 column. Protein containing eluted fractions were then pooled and dialyzed. The powder bio remediase protein was obtained after lyophilization (80 mg approximately) and stored in screw capped plastic container at room temperature for further work.

Preparations of Mortar Samples

Mortar samples were prepared by using commercially available Ordinary Portland cement (OPC) and fly ash pozzolana cement. Standard Ennor sand (IS 650) was used by mixing with cement (3:1 w/w) for mortar samples preparation. Cement to water ratio was kept fixed at 0.4 for all samples preparation. Standard mortar cubes of following dimension (70.6 mm x 70.6 mm x 70.6 mm) were cast as described by Ghosh et al. (2005) as follows: Control mortar cubes – Cement and sand mixture only. Bacterial cells incorporated mortar cubes – Cement + sand + bacterial cells (at three different concentrations as 104, 105, 106 cells /ml of water used).

Bio remediase protein incorporated mortar cubes – Cement + sand + bio remediase protein powder (1, 2, 3 and 4 μg/g cement used). No additional nutritional material, only excluding those present in the diluted cultures, was supplemented in the mortar cubes during casting. All the samples were cured under water as well as in open air after 24 h of casting. The compressive strengths of the mortar cubes were measured after 3, 7, 14, 28, 60, 120 days of curing. Test for water absorption and sulphate attack have been also made for both the addition of bacteria and its protein separately.

Results and Discussion

The purpose of this study was to observe the effect of the bacterial cells (BKH1) and its protein (bio remediase) on the mortar samples prepared by using Ordinary Portland cement and fly ash based pozzolana cements.

Strength

Figure 1 vividly describes the development of compressive strength of mortar cubes prepared by varying concentrations of bacterial cells using Ordinary Portland Cement. The samples were cured for different days at room temperature under water curing and their compressive strengths were measured. It was noted that compressive strength of the mortar cubes augmented with addition of the bacterial cells at every stages of curing compared to the control specimens (devoid of the bacterial cells). The effect is more pronounced in the case of Portland Pozzalana Based cement. The maximum increment in compressive strength was attained at the bacterial concentration of 105 cells per ml of water used in both cases mortar preparation. Similar observation has been obtained for air cured samples.

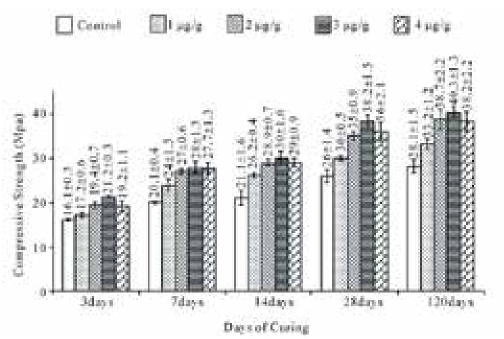


Figure 1. Mortar compressive strength with BKH1 cell under normal water curing

The bacterial protein (bio remediase , Sephadex G-100 column- purified pure) admixed mortar samples when cured at room temperature in water curing, displayed sharp increment of compressive strength at all ages (3, 7, 14, 28 and 120 days curing ages respectively) compared to normal control samples (Figure 2). Similar trend of results were obtained when compressive strength of pure protein-admixed air cured mortar samples were noted. There is also improvement in flexural strength of mortar using the OPC/PSC cement. The improvement is mainly due to the formation of new deposit Gehelenite (ref 10) as per SEM and XRD analysis.

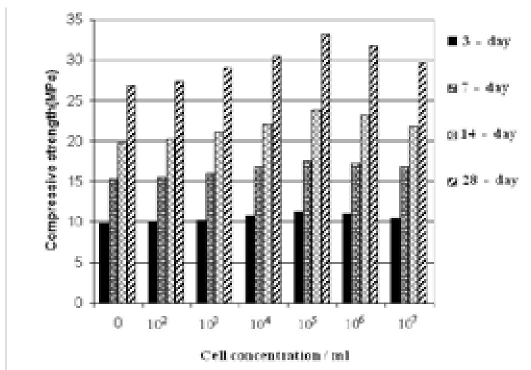


Figure 2. Mortar compressive strength with bio remediase protein under water curing.

Effect of Bacterial Cells and Bio remediase Protein on Water Absorption.

It was noted that mass of mortar samples impregnated with bacteria and also with the bio remediase protein were less altered as compared to the control samples. An average increase of only 2.2% and 4.7% in mass were noted for mortar samples impregnated with bacterial cells concentration of 105 cells per ml after 30 min and 72 h respectively. Whereas the bio remediase protein incorporated mortar samples showed less increase in mass (only 1.7% and 3.7% after 30 min and 72 h respectively when protein was used at 3 μg/g cement) due to water absorption. The effect is more or less similar in case of both OPC and PPC cement.

Effect of Bacterial Cells and Bio remediase Protein on Sulphate Resistance

The results of sulphate resistance tests distinctly asserted the positive influence of these biomaterials on cement mortar specimens. It was noted that mass of mortar samples impregnated with bacteria and also with the bio remediase protein were less affected as compared to the control samples. An increase of only 4.5% in mass was noted for samples impregnated with bacterial concentration of 105 cells per ml. Similarly 4.6% of mass increment was seen in bio remediase protein admixed mortar samples with protein concentration of 3 μg/g of cement used. It is thus evident from these data that bacterium/bio remediase protein incorporated biomaterials are less prone to sulphate attack compared to normal cement-sand mortar. Water absorption test and sulphate resistant test both thus confirm that bacterium BKH1 or its bio remediase protein amended biomaterials are more durable compared to normal mortar.

Viability of the Bio remediase over Long Period and Wide Temperature Range

Preserving them at two extreme conditions the activity of the protein remained almost unaffected. In performing these experiments, bio remediase protein powder was stored at 65°C and –20°C temperature respectively for 6 months. The protein was then used in preparation of mortar sample as stated earlier. The compressive strength of the stored bio remediase protein impregnated mortar samples was found to increase in similar fashion as observed in fresh protein samples earlier. This result suggests that the bio remediase protein can be stored and used for practical construction purposes without having any sophisticated storage facility.

Bio-Silicification Assay of Bio remediase Using OPC and PPC.

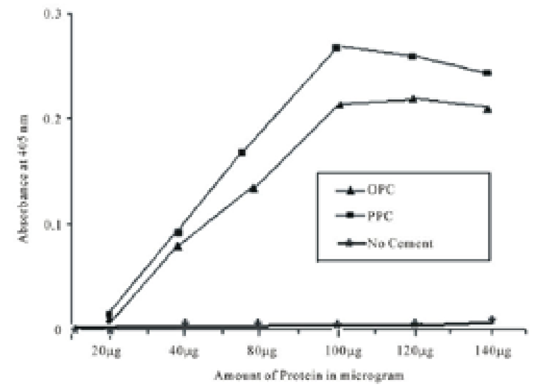


Figure 3. Bio-silicificaton assay of bio remediase protein using cement (50 mg) as substrate.

Biochemical assay for bio remediase protein using Ordinary Portland Cement and Portland Pozzolana Cement respectively as substrate clearly indicated the activity of the protein was more in PPC than OPC in all-experimental conditions (Figures 3 and 4).

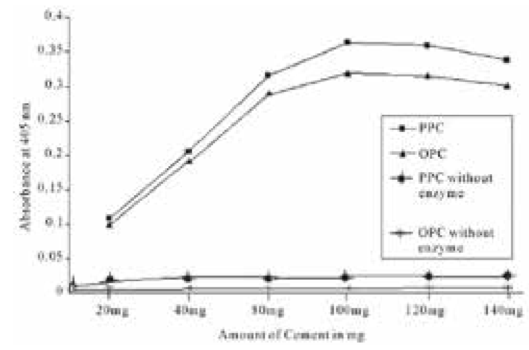


Figure 4. Bio-solidification assay of bio remediase protein (100 μg) using different concentrations of cement as substrate.

Comparative Analysis of the Effect of BKH1 on OPC and PPC

Previously it was observed that only 25% to 30% strength increment was achieved by using ordinary Portland cement with BKH1 cells or its specific bio remediase protein incorporated mortar samples [9, 10, 15]. This study showed 30% - 40% strength increment of PPC with the same bacterium or its bio remediase protein. The higher content of silicate in PPC helps to increase the activity of bio remediase enzyme. This clearly explained the higher strength improvement in pozzolana cement when BKH1 cells or its specific protein (bio remediase) was used.

Application

In addition to improvement in strength and durability of cementitious system, the bacteria can be also used as self-healing agent. Different species of bacteria are being already identified depending on their bio mineralization property, survival of bacteria in highly alkaline media, type of nutrient required and most notably health hazard. Further these bacteria can be used to repair cracks if injected from outside or by applying on the surface as paint. However, more study is needed to identify high performance bacteria. These bacteria also need nutrient for their survival which may not be available for longer period in the concrete mix. So the main aim should be to find out bacteria that can live for a longer time forming a shell within the concrete and remain in dormant stage. If the concrete cracks due to development of stress the outer thin shell then automatically breaks and the bio mineralogical action will starts immediately and become active. Over and above these bacteria should have a need of very small food (i.e. bacteria of low metabolic rate) and should be facultative anaerobic. Another advantage of the addition of bacteria is the reduction in the permeability of concrete due to the improved pore size distribution within the matrix. Also due their very small sizes, the chances of stress concentration are less as compared to the addition microcapsule or micro tubes normally used.

Conclusion

The study has shown that more such types of organism can be identified and efficiently used in the process of strength and durability improvement. There is scope and need for examining bio-logical processes that have influenced materials science on bio deposition and bio mineralization treatment such as microbial precipitation towards evolving a new methodology/technology for production of new sustainable construction materials with improved structural strength and durability. Using the new materials developed, it is possible to construct structures, which will be 'green' and 'sustainable', requiring optimum resources and energy. Bio remediase protein secreted by the bacterium BKH1 is a potential additive agent for different types of cements. The increment of strength and other essential features of mortar/concrete materials are substantially higher for pozzolana cement based mortar/concrete materials than ordinary Portland cement based specimens when admixed to bio remediase protein. Opulence of silica in fly ash pozzolana cements is behind the enhanced activity of the bio remediase protein that ushers a new hope in future construction technology.

Reference

Mehta, P. K. "Advancement in Concrete Technology," Journal of Concrete International, Vol. 96, 1999, pp. 69-75.

Jonkers, H. M. "Self-Healing Concrete: A Biological Approach," In: S. Van der Zwaag, Ed., Self-Healing Materials: An Alternative Approach to 20 Centuries of Material Science, Springer, Inc., The Netherlands, 2007, pp. 195-204.

Ramachandran, S. K., Ramkrishnan,V., Bang, S. S. "Remediation of Concrete Using Microorganisms," ACI Material Journal, Vol. 98, No. 1, 2001, pp. 3-9.

Broekmans, M. A. T. M. "Deleterious Reactions of Aggregate with Alkalis in Concrete," Review of Mineralogy and Geochemistry, Vol. 74, No. 1, 2012, pp. 279-364.

Skinner, W. C. H., Jahren, H. A. "Biomineralization," In: W. H. Schlesinger, Ed., Treatise on Geochemistry, Elsevier, 2003, pp. 117-184.

Siddique, R and Chahal, N.K. (2011). Effects of ureolytic bacteria on concrete properties. Construction and Building Material, 25,379 1-3 80

Belkova, L. N. "Biomineralization in Natural Environments: The Effect of Microorganisms Inhabiting Hot Spring Water and Biomats on Mineral Formation," Geophysics Research Abstract, No. 7, 2005.

Boskey, A. L. "Biomineralization: An Overview," Connective Tissue Research, Vol. 44, No. 1, 2003, pp. 5-9.

Ghosh, P., Mandal, S., Chattopadhyay, B. D., Pal, S. "Use of Microorganisms to Improve the Strength of Cement-Mortar," Cement and Concrete Research, Vol. 35, No. 10, 2005, pp. 1980-1983.

Ghosh, S., Biswas, M., Chattopadhyay, B. D., Mandal, S. "Microbial Activity on Microstructure of Bacteria Modified Mortar," Cement and Concrete Composites, Vol. 31, No. 2, 2009, pp. 93-98.

Graef, B. De., Windt, W. De., Dick, J., Verstraete, W., De Belie, N. "Cleaning of Concrete Fouled by Lichens with the Aid of Thiobacilli," Material Structure, Vol. 38, No. 284, 2005, pp. 875-882.

Bang, S. S., Galinat, J. K., Ramakrishnan, V. "Calcite Precipitation Induced by Polyurethane-Immobilized Bacillus pasteurii," Enzyme and Microbial Technology, Vol. 28, No. 4-5, 2001, pp. 404-409.

Rodriguez-Navarro, C., Rodriguez-Gallego, M., Ben Chekroun, K. and Gonsalez-Munoz, M. T. "Conservation of Ornamental Stone by Myxococcus xanthus-Induced Carbonate Biomineralization," Applied and Environmental Microbiology, Vol. 69, No. 4, 2003, pp. 2182-2193.

Biswas, M., Majumdar, S., Chowdhury, T., Chattopadhyay, B. D., Mandal, S., Halder, U. and Yamashaki, S. "Bioremediase a Unique Protein from a Novel Bacterium BKH1, Ushering a New Hope in Concrete Technology," Enzyme and Microbial Technology, Vol. 46, No. 7, 2010, pp. 581-587.

Chattopadhyay, B. D., Thakur, A. R., Poddar, R. K. and Dasgupta, D. "Effect of Calcium Ion on Methanosarcine barkeri MS," Indian Journal of Experimental Biology, Vol. 31, 1993, pp. 738-742.

Cha, J. N., Shimizu, K., Zhou, Y., Christianssen, S. C., Chmelka, B. F., Stucky, G. D. and Morse, D. E. "Silicatein Filaments and Subunits from a Marine Sponge Direct the Polymerization of Silica and Silicones in Vitro," Proceedings of National Academy of Sciences, Vol. 96, No. 2, 1999, pp. 361-365.

Bureau of Indian Standard, "IS 8112: Specification for 43-Grade Ordinary Portland Cement," New Delhi, India, 1989.

Bureau of Indian Standard, "IS 650: Specification for Standard Sand from Natural Sources of Ennor, Tamilnadu District, India for Concrete," New Delhi, India, 1991.

Douglas, H. A., Daniel, M. D., Daniel, E. M. and Ilha, A. A. "Non-Peptide, Silicatein Alpha Inspired Silica Condensation Catalyst," Polymer and Material Science Engineering, Vol. 90, 2004, pp. 239-241.

Jonkers, H. M. et al, Self-healing of cracked concrete: A bacterial approach, Proceedings of FRAMCOS 6 : Fracture Mechanics of Concrete, Catania, Italy, 17-22 June 2007, pp.- 1821-1826

Belie, N. D. et al., Bacterial carbonate precipitation as an alternative surface treatment for concrete, Construction and Building Materials, 2008, Vol-22, Issue- 5, pp. - 875-885

Author

Dr. Saroj Mandal is presently Professor of Civil Engineering Department, Jadavpur University, Kolkata. He has a distinguished professional and academic career and became professor at the age of 40. Professor Mandal has had the privilege to guide Ph.D. and Master students leading to the publication of over fifty in reputed Journals and Conferences. He has wide ranging interests and has researched, consulted and published widely in the area of concrete material and structures. E-mail: sarojmandal@rediffmail.com

Ambuja Techinical Journal / February 2017

Fatigue Life of Self Compacting Concrete

Sanjay Goel

Abstract

The fatigue life of concrete is of random nature and shows large scatter even under controlled conditions of testing. Thus it becomes essential to judge the variability of the fatigue life of concrete to estimate the fatigue life of structures like bridges, off-shore structures, pavements which are subjected to repetitive loading. This paper presents the results of an extensive experimental study conducted to investigate the performance of Self Compacting Concrete (SCC) under fatigue loading . A suitable SCC mix was designed which passes the workability tests prescribed by EFNARC. To obtain the fatigue life data, beam specimens of size 100mm x 100mm x 500mm were cast and tested under four point flexural fatigue loading at different stress levels ranging from 0.85 to 0.65. The variability of fatigue life is measured by estimating the distribution parameters i.e. shape parameters of two-parameter Weibull Distribution for the fatigue life data of SCC. Three methods graphical method, method of moments and method of maximum likelihood estimate has been used to obtain the distribution parameters of the Weibull distribution. It has been observed that there is considerably less variability in the distribution of fatigue life of SCC as compared to Normally Vibrated Concrete (NVC), which will instill greater confidence in the concrete technologists and designers in using SCC for structures subjected to fatigue loading.

Keywords

Fatigue life, Shape parameter, Self Compacting Concrete, Variability, Weibull Distribution Dr. Sanjay Goel is presently working as Assistant Professor in the department of Civil Engineering at DAV Institute of Engineering and Technology, Jalandhar in Punjab. His research interests are recycling of waste materials in concrete composites and self compacting concrete.

Introduction

Self Compacting Concrete (SCC) has become the most sought after construction material in the recent past due to its substantial benefits over conventional Normally Vibrated Concrete (NVC). Self compacting concrete has the ability to fill formworks and compact under its own weight without the use of vibration. It fills all recesses, reinforcement spaces and voids, even in highly congested reinforced concrete members and flows free of segregation. The major applications of SCC are in bridge decks and piers, pavements, road surfaces, rapid transportation systems, industrial yards, etc (Okamura & Ouchi 1999; Domone 2005). Since most of these structures are predominantly subjected to fatigue loading, thus it becomes essential to look into the fatigue behavior of SCC under fatigue loading especially under flexural fatigue loading.

Majority of the research reported in literature has focused attention on workability properties like passing ability, filling ability and resistance to segregation, etc. of fresh SCC and mechanical properties such as compressive strength, flexural strength, splitting tensile strength, elastic modulus, creep and shrinkage etc. of hardened SCC under statically applied loads (Persson 2000; Brouwers and Radix 2005; Domone 2005; Sonebi et al. 2007; Domone 2007). Studies on SCC looked into the effect of different fillers like fly ash, limestone powder, blast furnace slag, silica fume, metakaolin, chalk powder, etc. on rheological and hardened mechanical properties of SCC under statically applied loads and its durability (Karjinni et al. 2009; Singh et al. 2009; Turkel and Kandemir 2010). Some researches have also shown interest in mix proportioning methods for SCC (Su et al. 2001).

A number of studies have been carried out to investigate the fatigue properties of NVC as fatigue strength is an important parameter in the design of concrete structures subjected to repetitive loads during their service life.

Table 2: Workability Tests on Fresh SCC Mix

Workability Test	Parameter	Result obtained	EFNARC Guidelines
Slump flow Test	T500 (sec)	3.12	2 - 5 sec
	Slump Flow spread (mm)	750	650 – 800 mm
J-Ring Test	T500J (sec)	3.26	3 – 6 sec
	Flow spread (mm)	725	600 – 750 mm
	Blocking step Bj (mm)	6.5	0 – 10 mm
V-funnel Test	V-funnel Time (sec)	7.28	6 – 12 sec
L-Box Test	L- box Passing Ability	0.91	0.8 -1.0

S-N curves were generated and the effect of stress reversal, loading frequency, aggregate type, air-content, water/cement ratio on the fatigue strength of NVC under constant and variable flexural loading were studied (Kesler 1953; Hilsdorf & Kesler 1966; Raithby 1972; Tepfers & Kutti 1979; Hsu 1981). Since fatigue test data of NVC show significant scatter even under carefully controlled conditions, attempts have been made to incorporate the probabilistic concepts to predict the fatigue resistance of concrete structures. The variability in the fatigue life data of NVC has been extensively modeled using two parameter Weibull distribution. The different methods have been proposed by researchers to obtain the distribution parameters from the S-N relations (Oh 1986, 1991; Shi et al. 1993; Mohammadi & Kaushik 2005).

Research Significance

The reported literature available on SCC shows that a significant work has been done on the mechanical properties of SCC under statically applied loads. Although, considerable amount of research work has been carried out to investigate the fatigue behaviour of NVC, but little or no information exists in literature on the fatigue characteristics of SCC, which prompts one to work in this direction. Therefore an investigation was planned to study the fatigue behaviour of SCC at different stress levels and to look at the beneficial effects of SCC, on the variability in the distribution of fatigue.

External Programme

The mix proportions of the SCC used in the investigation is presented in Table-1.

Table 1: Mix Proportions for SCC

Cement kg/m3	Flyash kg/m3	Fine Aggregates kg/m3	Coarse Aggregates kg/m3	Superplastisizer (by weight of cement)
410	205	846	602	1.7%

The EFNARC (2005) guidelines were followed for basic workability tests of SCC and the results are summarized in Table-2.

The mix was placed into the moulds without any mechanical vibrations or tamping. The beam specimens of 100mm x 100mm x 500mm and cubes specimens of 150mm x 150mm x 150mm in size were cast in different batches. The quality of each batch of concrete was checked by obtaining the 28 days compressive strength for each batch. The average 28 day compressive strength of the SCC mix was 35.9 MPa. The average static flexural strength of the SCC mix used in the investigation was 4.85 MPa. After the establishing the static flexural strength of a particular batch containing seven specimens, the remaining beams were tested in flexural fatigue. The beam specimens were tested in flexural fatigue and static flexural loading over a span of 450 mm loaded at third points on the 100kN servo controlled closed loop MTS universal testing machine. The flexural fatigue tests were conducted at different stress levels S (S = fmax/fr), ranging from 0.85 to 0.65 under constant amplitude, sinusoidal non-reversed loads at a frequency of 12 Hz. The fatigue stress ratio R (R = fmin/fmax) was kept constant at 0.10 throughout the investigation. The number of cycles to failure of each specimen at a particular stress level was recorded as fatigue life N.

Table 3: Weibull Parameters for the Fatigue Life Data of SCC

	Graphical Method		Method of Moments		Method of Maximum Likelihood		Average	
	□	u	□	u	□	u	□	u
S = 0.85	3.9354	2118	4.5210	2102	4.5850	2099	4.3471	2106
S = 0.80	3.4942	15895	3.8877	15807	3.9754	15774	3.7858	15825
S = 0.75	2.9514	67198	3.4408	66372	3.7320	66285	3.3747	66618
S = 0.70	2.8350	193667	3.2381	191453	3.4490	191237	3.1740	192119
S = 0.65	2.7279	1475243	2.9839	1385603	3.2485	1384905	2.9867	1415250

Analysis of Fatigue Life Data

Fatigue Life Distribution for SCC

Researchers extensively followed the two-parameter Weibull distribution, which shows increasing hazard function with time and based on more convincing arguments, to depict the life distribution of fatigue data of engineering materials (Kennedy & Neville 1986; Oh 1986). Many researchers had confirmed that distribution of fatigue life of NVC approximately follows the two-parameter Weibull distribution (Oh 1986, 1991; Mohammadi & Kaushik 2005). Thus in this study, it was proposed to use the two-parameter Weibull distribution for modeling of the fatigue life data of SCC. Firstly the application of Weibull distribution for the fatigue life distribution of SCC will be verified using Graphical method. Then the parameters of the Weibull distribution will be estimated from the experimental data for each different fatigue stress level using graphical method, method of moments and method of maximum likelihood estimate. For this purpose some of the fatigue test data points recorded as fatigue life N for SCC at different stress levels were rejected as outliers by applying Chauvenet's criterion (Kennedy & Neville 1986; Oh 1991; Mohammadi & Kaushik 2005) and were excluded from further analysis.

Establishing the Weibull Distribution using Graphical Method

The survivorship function LN(n) of two-parameter Weibull distribution may be written as follows(Oh 1986, 1991; Mohammadi & Kaushik 2005):

$$L_N = \exp\left[-\left(\frac{n}{u}\right)^{\alpha}\right] \quad (1)$$

Where n is specific value of random variable N, □□is the shape parameter at stress level S, u is the scale parameter at stress level S. Taking the logarithm twice of both sides of Eq. (1)

$$\ln\left[\ln\left(\frac{1}{L_N}\right)\right] = \alpha \ln(n) - \alpha \ln(u) \quad (2)$$

Equation (2) represents a linear relationship between ln[ln(1/LN)] and ln(n) and can be used to verify the use of two-parameter Weibull distribution for fatigue test data at a particular stress level. A graph is then plotted between ln[ln(1/LN)] and ln(n). To obtain a graph, the fatigue test data at a given stress level is arranged in ascending order. The empirical survivorship function LN can be calculated from the following equation (Oh 1986, 1991; Mohammadi & Kaushik 2005).

$$L_N = 1 - \frac{i}{k+1} \quad (3)$$

where i is failure order number, and k is number of fatigue data points at given stress level S. If the data follows a linear trend on the graph, it indicates that the two parameter Weibull distribution is a reasonable assumption for the statistical description of fatigue life data of SCC at a given stress level. The shape parameter □ and the scale parameter u can be obtained from the regression analysis. Figure 1 shows the plot of the fatigue life data of SCC at S= 0.85, 0.80, 0.75, 0.70 and 0.65. It can be observed that the data points fall approximately along a straight line, which indicates that two parameter Weibull distributions is reasonably valid for the distribution of fatigue life of SCC at all the tested stress levels. The value of the correlation coefficient Cc greater than 0.97 at all the stress levels as shown in Fig.-1, also strengthened the same fact. The values of the Weibull parameters □□ and u obtained from the graphical method are presented in Table-3.

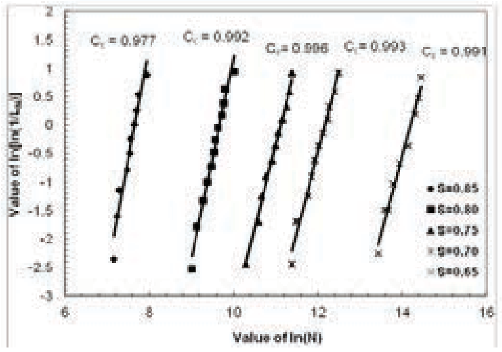


Figure 1: Graphical Analysis of fatigue life data of SCC at different stress levels S

Weibull Distribution Parameters by Method of Moments

This method requires sample moments like mean and variance to calculate the parameters of the Weibull distribution. Following relationships can be used to obtain the parameters □ and u by method of momnets (Wirsching and Yao 1970; Oh 1991; Shi et al. 1993; Mohammadi and Kaushik 2005):

$$□ = (CV)g^{-1.08} \quad (4)$$

and

$$u = \frac{\mu}{\Gamma\left(\frac{1}{\alpha}+1\right)} \quad (5)$$

where □□is the sample mean of the fatigue life data at given stress level, CV (= □/□□□□□is standard deviation of sample□ is the coefficient of variation of the data, and the Γ( ) is the gamma function. The parameters of the Weibull distribution for the fatigue life data of SCC for different stress levels tested in this investigation i.e. 0.85 to 0.65 were estimated using Eqs. (4) and (5). and are listed in Table-3.

Weibull Distribution Parameters by Method of Maximum Likelihood Estimate

The distribution parameters for the Weibull distribution can also be obtained using the method of maximum likelihood estimate. The probability density function of Weibull distribution may be written as follows *(Oh 1991; Mohammadi and Kaushik 2005):*

$$f_N(n) = \frac{\alpha}{\theta} n^{\alpha-1} \exp\left[-\frac{n^{\alpha}}{\theta}\right] \quad (6)$$

where

θ = u□□ (7)

The maximum likelihood equations can be modified as follows:

$$\frac{\sum_{i=1}^{k} n_i^{\alpha^*} \ln(n_i)}{\sum_{i=1}^{k} n_i^{\alpha^*}} - \frac{1}{\alpha^*} = \frac{1}{k}\sum_{i=1}^{k} \ln(n_i) \quad (8)$$

$$\theta^* = \frac{1}{k}\sum_{i=1}^{k} n_i^{\alpha^*} \quad (9)$$

where □* and □* are the maximum likelihood estimates of □ and □□□respectively□□The value of shape parameter is first obtained by solving the Eq. (8) by an iterative procedure. To start the iteration process, the value of □ obtained by any of the two preceding methods i.e. graphical method and method of moments can be used as a first trial. The value of u can then be obtained from Eq. (7). The parameters for the Weibull distribution obtained by the method of maximum likelihood for fatigue life data of SCC corresponding to different stress levels tested are tabulated in Table-3. It can be observed from the Table-3 that the distribution parameters obtained from the three methods are almost similar. The average values of the shape parameter for the fatigue life data of SCC at different

Table 4: Shape Parameters for the Fatigue Life Data of SCC and NVC

	S = 0.85	S = 0.80	S = 0.75	S = 0.70	S = 0.65
SCC (Present Work)	4.3471	3.7858	3.3747	3.1740	2.9867
NVC (Oh 1986, 1991)	3.8920	2.8000	2.5230	-	2.2030
NVC (Mohammadi and Kaushik 2005)	3.5457	2.7782	-	2.2393	-

stress levels obtained by different methods of analysis are also listed in the same table.

For comparison purpose the results of the shape parameters obtained in this investigation for fatigue life of SCC at different stress levels have been plotted in Figure- 2, against the values of the shape parameter as obtained for NVC in some of the previous studies. The values of the shape parameter for the fatigue life data of NVC in the previous studies along with those obtained for the fatigue life data of SCC in the present investigation are also listed in Table- 4 for reference.

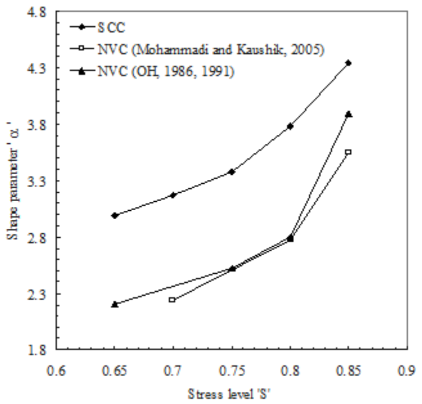


Figure 2: Comparison of shape parameters of SCC and NVC

Table 4: Shape Parameters for the Fatigue Life Data of SCC and NVC

It has been observed form Figure-2 and Table- 4 that the shape parameter for the fatigue life data of SCC decreases with the decrease in the stress level thus indicating higher variability in the distribution of fatigue life of SCC at lower stress levels. Similar results have been reported by previous investigators for the fatigue life of NVC (Oh 1991; Mohammadi and Kaushik 2005). It can be observed that in general, that at a particular stress level, there is reduction in the variability in the distribution of fatigue life of SCC as compared to that of NVC. This can be interpreted from the fact that higher values of the shape parameter indicate lower variability in the distribution of fatigue life. It can be seen from Figure- 2 and Table- 4 that all the stress levels tested, the values of the shape parameter for the fatigue life of SCC are higher as compared to those of NVC. More specifically, there is an increase in the shape parameter for SCC as compared to NVC to the tune of 17% at stress level S = 0.85; 36% at stress level S = 0.80; 34% at stress level S = 0.75; 41% at stress level S = 0.70 and 36% at stress level S = 0.65. As a result of this, a maximum decrease of about 14% in the coefficient of variation in fatigue life data of SCC is observed as compared to NVC. The reduction of variability in the distribution of fatigue life data of SCC compared to NVC may be attributed to the relatively more homogeneous composition of SCC.

Conclusion

Flexural fatigue life data was obtained for SCC and analysed to study the variability in the fatigue life distribution of SCC in comparison to the conventional NVC. The probability distribution of SCC at different stress levels have been examined and it is established that, at a particular stress level, the distribution of fatigue life of SCC can be described by two-parameter Weibull distribution with statistical correlation coefficient exceeding 0.97. The distribution parameters were obtained in this investigation using graphical method, method of moments and method of maximum likelihood estimate, at all the given stress level for SCC. The comparative study has shown that there is an increase in the value of shape parameter '□' for SCC at all the stress levels compared to that of NVC as obtained in previous investigations. A maximum increase of 41% in the shape parameter and a maximum decrease of 14% in the variability of fatigue life data of SCC has been observed with respect to NVC. Thus the results of the present investigation shows reduced scatter in fatigue life for SCC which depicts a better performance of SCC under flexural cyclic loading.

References

1. Brouwers, H. J. H. and Radix, H. J. (2005), Self Compacting Concrete: Theoretical and Experimental Study, Cement and Concrete Research; 35, 2116-2136.
2. Domone, P. L. (2005), Self Compacting Concrete: An analysis of case studies, Cement and Concrete Composites; 28, 197-208.
3. Domone, P. L. (2007), A Review of the Hardened Mechanical Properties of Self Compacting Concrete, Cement & Concrete Composites; 29, 1-12.
4. EFNARC (2005), The European Guidelines for Self Compacting Concrete, Specification, Production and Use, EFNARC; pp. 68.
5. Hilsdorf, H. K. and Kesler C. E. (1966), Fatigue Strength of Concrete under varying Flexural Stresses, ACI Materials Journal; 63, 1059 -1076.
6. Hsu, T. C. C. (1981), Fatigue of Plain Concrete, ACI Materials Journal; 78, 292–305.
7. Karjinni, V. V., Anadinni, S. B. and Patil, D. S. (2009) An Investigation on the Characteristic Properties of High Performance SCC with Mineral Admixtures, Indian Concrete Journal; 17-19.
8. Kennedy, J. B. and Neville, A. M. (1986), Basic Statistical Methods For engineers and Scientists, Dun-Donnelley, New York.
9. Kesler, C.E. (1953), Effect of speed on Flexural Strength of Plain concrete, HRB Proceedings, 32, 251-258.
10. Mohammadi, Y. and Kaushik, S. K. (2005), Flexural fatigue-Life Distributions of Plain and Fibrous Concrete at Various Stress Levels, Journal of Materials in Civil Engineering, ASCE; 17(6), 650-658.
11. Oh, B. H. (1986), Fatigue Analysis of Plain Concrete in Flexure, Journal of Structural Engg, ASCE; 112(2), 273-288.
12. Oh, B. H. (1991), Fatigue-Life Distributions of Concrete for various Stress Levels, ACI Materials Journal; 88(2), 122-128.
13. Okamura, H. and Ouchi, M. (1999), Self - Compacting Concrete Development, Present, and Future, Proceedings of 1st International RILEM Symposium on Self-Compacting Concrete; 3-14.
14. Persson, B. (2000), A Comparison between Mechanical Properties of Self compacting Concrete and the Corresponding Properties of Normal Concrete, Cement and Concrete Research; 31, 193-198.
15. Raithby, K. D. (1972), Flexural Fatigue Behaviour of Plain Concrete, Fatigue Engineering Materials, Structural; 2, 269 - 278.
16. Shi, X. P., Fwa, T. F., and Tan, S. A. (1993), Flexural Fatigue Strength of Plain Concrete, ACI Material Journal; 90(5), 435–440.
17. Singh, B., Kumar, R., and Mukati, A.S. (2009), SCC Mixes with Limestone and Chalk Powder - The Indian Experience, Indian Concrete Journal; 9-17.
18. Sonebi, M., Grünewald, S., and Walraven, J. (2007), Passing-Ability and Filling - Ability of Self Consolidating Concrete, ACI Materials Journal; 104(2), 162-170.
19. Su, N., Hsu, K. C. and Chai, H. W. (2001), A Simple Mix Design Method for Self Compacting Concrete, Cement and Concrete Research; 31, 1799-1807.
20. Tepfers, R. and Kutti, T. (1979), Fatigue Strength of Plain, Ordinary and Light Weight Concrete, ACI Material Journal; 76(5), 635-652.
21. Turkel, S. and Kandemir, A. (2010), Fresh and Hardened properties of SCC made with Different aggregate and Mineral Admixtures, Journal of Materials in Civil Engineering, ASCE; 22(10), 1025-1032.

Author
Dr. Sanjay Goel is working as Assistant Professor in the department of Civil Engineering at DAV Institute of Engineering and Technology, Jalandhar, Punjab, INDIA. He received his Master's in Structural Engineering the year 2003 and earned his Ph.D. in the year 2012. He has more than 13 years of teaching, research and educational experience. His research interests are Self-Compacting Concrete, Fatigue of Concrete Composites, Fibre Reinforced Concrete, Recycling of Waste Materials in concrete.

Supriya Sarkar

Abstract

Bubble Deck is an innovative new technology that replaces a significant percentage of a concrete slab's mass with hollow or foam filled plastic balls. In technical terms, it creates a voided biaxial slab. The "bubbles" are sandwiched between top and bottom meshes creating a natural cell-like structure that when concreted, performs just like a traditional solid reinforced concrete slab. Bubble Deck, however, has all kinds of advantages over the traditional solid slab. The voids in the Bubble Deck slab reduce the dead weight up to 35%, allowing for a reduction in building structure and foundations, thereby saving materials and costs. Bubble Deck can span far longer than a solid slab (20 to 40 times the deck thickness) in all directions, and without the need for beams! The result? Open floor plates, minimal structure, and flat soffits. It can also achieve astonishing cantilevers up to 10 times the deck thickness. Bubble Deck slabs can follow any shape, allowing for ultimate design creativity. It also provides future flexibility, since adding slab openings is easy and cost effective. With Bubble deck, construction time and costs can be greatly reduced. Lighter weight materials decrease transportation costs and require less expensive lifting equipment. Pipes, ductwork, and other penetrations are easily incorporated into the slab. Bubble Deck is also green friendly and qualifies for LEED points. Made from recycled materials, it actually uses less material overall. 1 kg of plastic replaces 100 kg of concrete.

• Build More With Less

Bubble Deck is the patented integration technique of linking air, steel, and concrete in a two-way structural slab. Hollow plastic balls are inserted into the slab and held in place by reinforcing steel. The end result eliminates the use of concrete that has little carrying effect while maintaining the two-way span (biaxial) strength.

• Reduced Overall Cost

Bubble Deck eliminates up to 35% of the structural concrete. When coupled with the reduced floor thickness and facade, smaller foundations and columns, construction costs can be reduced by as much as 10%.

• Faster Construction

With virtually no formwork, no downturn beams or drop heads, and fast coverage of typically 350ft2 per panel, using Bubble Deck means floor cycles up to 20% faster than traditional construction methods. Regardless of project size, shape or complexity; simply shore, place, and pour to quickly install concrete decks.

• Lower Risk

Off-site manufacturing, fewer vehicle trips and crane lifts as well as simple installation all combine to minimize operating risks, as well as lower health & safety risks. As a result, major projects around the world have chosen the BubbleDeck technology as the low-risk way to build large and complex projects.

• LEED Compatible

The Bubble Deck system offers a wide range of advantages in building design and during construction. There are a number of green attributes including; reduction in total construction materials, use of recycled materials, lower energy consumption and reduced CO2 emissions, less transportation and crane lifts that make Bubble Deck more environmentally friendly than other concrete construction techniques. Technical information:

Technical information:-

Thermal insulation

• Methodology

Thermal resistance determined by calculation undertaken in accordance with BS EN ISO 6946:1997, with bubbles approximated to cubic shape with same area and aspect ratio in accordance with this standard. Calculations independently undertaken by Jersey Energy, Services and Energy Consultants

Table 1 : Thermal resistance values

Bubble Deck Slab	Thickness	Bubble Deck Thermal Resistance m2k/W	Solid Slab Same Thickness m2k/W	Bubble Deck Percentage Improvement
BD 230	230mm	0.1546	0.1111	39%
BD 280	280mm	0.1847	0.1375	34%
BD 340	340mm	0.2102	0.1659	27%
BD 390	390mm	0.2325	0.1905	22%
BD 450	450mm	0.2583	0.2205	17%

• Comparison with solid slabs

While Bubble Deck slabs are not designed to provide thermal insulation due to encapsulation of the air bubbles within the centre of the concrete slab, the technology achieves between 17% to 39% higher thermal resistance than an equivalent solid slab of the same depth. Bubble Deck slabs can therefore make a useful contribution towards the thermal insulation achieved by the overall construction.

Thermal resistance values

• Condensation risk

Designer's attention is drawn to the fact that non-insulated concrete slabs forming part of the external building envelope can produce cold surfaces where certain conditions, dependent upon the relative humidity and dew point, may result in formation of condensation. It is recommended a condensation risk analysis is undertaken where Bubble Deck slabs form part of the external building envelope.

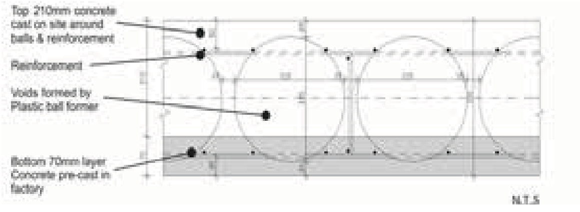
Case Study:-
Sound Insulation

Criteria

Approved Document E, 2003 Edition: Floor Types 1 or 2 (Page 38 Diagram 3-1) requires a solid concrete slab (cast in-situ or with permanent shuttering) to have a minimum mass of either 365 kg/m^2 (Clause 3.29 Floor Type 1.1C), or 300 kg/m^2 (Clause 3.67 Floor Types 2.1C and 2.1C (b)).

BubbleDeck Slab Construction

The BubbleDeck system are semi pre-cast 2.4 metre wide elements with 70mm permanent concrete shuttering which are butted together on site, loose reinforcement inserted across the element joints, and the remaining concrete cast in-situ to form the finished slab. Construction of the BD280 type slab comprised:



Mass Calculation - Type BD230 Element

Calculate volume of equivalent 1metre x 1 metre solid slab 230mm thick, and then deduct volume of air voids (formed by te balls) in 1 metre x 1 metre BubbleDeck slab to produce volume of concrete in 1 metre x 1 metre BubbleDeck slab. Multiply volume by weight of concrete to give mass of BubbleDeck slab per m^2.

Volume of solid slab = 1x1x0.23 = 0.23 m^3. Volume of air voids = 25 no 180mm diameter balls per m^2 Volume of sphere is diameter^3 x 0.5236. Therefore volume of each ball is (0.18x0.18x0.18) x 0.5236 = 0.0030536 m^3 x 25no. per m^2 = 0.07634 m^3. Net volume of 230mm thick BubbleDeck slab is therefore 0.23 m^3, minus 0.07634 m^3 = 0.15366 m^3.

Mass of 230mm thick BubbleDeck slab is therefore 0.15366 m^3 x 2400 kg/m2 (Weight of concrete with 2% reinforcement) = 368.8 kg/m^2.

Mass of 368.8 kg/m^2 for 230mm thick BubbleDeck slab exceeds Approved Document Part E requirment for Floor Types 1 or 2.

Other BubbleDeck Slab Types

All thicker BubbleDeck slab types have increased mass, exceeding Approved Document Part E requirement for Floor Types 1 or 2, as follows:

Slab Type	Thickness	Mass kg/m^2
BD280	280mm	460
BD340	340mm	550
BD390	390mm	640
BD450	450mm	730

The appropriate Bubble Deck slab version is bespoke engineered to suit building conjuration, span length between supports, applied loadings and vertical alignment of supports. Indicative spans are given as a guide to what can be achieved. Established from full calculation FE analysis these are based on 20 mm. concrete cover to bottom rebar (minimum 1 hour resistance); live / dead load of 3 / 1.5 kN/m and lightweight external envelope maximum 6 kN/m line load. Completed slab mass and Concrete Quantity based on 3 x 9 meter pre-cast panels with 35 kg/m2 total reinforcement.

Summary & Conclusion:

The engineering solution that radically improves building design and performance while reducing the overall cost:-

The revolutionary Bubble Deck method virtually eliminates concrete from the middle of a slab not performing any structural function, thereby dramatically reducing structural dead weight. The patented Bubble Deck technique is based on the direct way of linking air and steel. Void formers in the middle of a flat slab eliminates 35% of a slabs self-weight removing constraints of high dead loads and short spans. Incorporation of recycled plastic bubbles as void formers permits 50% longer spans between columns. Combination of this with a slab construction approach spanning in two directions – the slab is connected directly to in situ concrete columns without any beams -produces a wide range of cost and construction including:

- **Design Freedom** - layout easily adapts to irregular & curved plan layouts.
- **Reduced Dead Weight** - 35% removed allowing smaller foundation sizes.
- **Longer spans between columns** - up to 50% further than traditional structures.
- **Down stand Beams eliminated** - quicker & cheaper erection of walls and services.
- **Load bearing walls eliminated** - facilitating MMC with lightweight building envelopes.
- **Reduced concrete usage** - 1 kg recycled plastic replaces 100 kg of concrete.
- **Environmentally Green and Sustainable** - reduced energy & carbon emissions.

The overall area is divided down into a series of planned individual elements, tailored up to a standard of 16 x 3 m depending on project, which are manufactured using MMC techniques. These elements comprise the top and bottom reinforcement mesh, sized to suit the project, joined together with vertical lattice girders with the bubble void formers trapped between the top and bottom mesh reinforcement to their optimum position. This is termed a 'bubble-reinforcement' sandwich which is then cast into bottom layer of pre-cast concrete, encasing the bottom mesh reinforcement, to provide permanent formwork within part of the overall slab depth. On site the individual elements are then 'stitched' together with loose reinforcement simply laid centrally across the joints between elements. Splice bars are inserted loose above the pre-cast concrete layer between the bubbles and purpose made mesh sheets tied across the top reinforcement mesh to join the elements together. After the site concrete is poured and cured this technique provides structural continuity across the whole slab – the joints between elements are then redundant without any structural – to create a seamless floor slab. The Bubble Deck technology has proved to be highly successful around the World since invented in the 90'ies by Mr. Breuning with over 3 million square meters of slabs have been constructed using the Bubble Deck system in all types of multi-storey buildings.

The Bubble Deck system is a simple solution that eliminates non - working dead load in concrete slabs while fully retaining strength:-

Green Credentials:

By virtually eliminating concrete in the middle of a Bubble Deck slab makes a significant contribution to reducing environmental impact. Guidance from the ODPM requires the direct environmental effects of buildings to be considered, including usage of natural resources and emissions resulting from construction. Not only is concrete usage reduced by up to 50% within a buildings structure but knock-on benefits can be realized through reduced foundation sizes. The Bubble Deck technology can make a substantial contribution towards achieving **BREEAM** targets.

- Every 5,000 m2 of Bubble Deck slab can save:
  - -1,000 m3 site concrete.
  - -166 ready mix lorry trips.
  - -1,798 Tones of foundation loads – or 19 less piles.
  - -1,745 GJ energy used in concrete production & haulage.
  - -278 Tones of CO2 - green house gases – emissions.

Fig:-2 Some Bubble Deck Constructions

Bubble Deck was used for the Life Sciences Building because of the larger spans that were achieved compared to a site cast concrete structure without the need for post-tensioning or pre-stressed sections. The total construction time for the structure was reduced and allowed the consultants to fast track the design without the interior design finalized. The total time from design inception to completion of structure was less than 12 months. The contractor was able to set over 60,000ft2 in a month and allowed the concrete structure to be complete before the start of fall classes.

Author

Supriya Sarkar is a graduate Civil Engineer. He also completed his MBA in Construction Management. He is a Member of Indian Green Building Council, Member of International Association of Engineers, and Consulting Civil Engineer, L.B.S of T.N.A.A.

Ultra High Performance Self Compacting Concrete using Pozzolanic Materials

Rahul Mathur

Introduction to the Ultra High Performance (UHPC) Concept

CONCRETE is the widely used construction material. It is produced by proper proportioning of ingredients such as cement, water, coarse aggregate and fine aggregate, so as to satisfy the required characteristics in green and hardened state. HPC have same constituents as that of concrete along with one of the following product such as organic admixture, supplementary cementitious materials, fibers etc and which are not limited to the final compressive strength, but include rheological properties, early age characteristics, deformability properties and durability aspects. Thus the purpose of mix proportioning is to obtain concrete that will have suitable workability, maximum density, and strength at specified age, dimensional stability and specified durability. Proportioning of concrete mixes is highly trial intensive.

As defined by ACI, "HPC is defined as a concrete meeting special combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices". Characteristics that may be considered critical for particular application.

- Ease of placement
- Compaction without segregation
- Early age strength
- Long - term strength and mechanical properties
- Permeability
- Density
- Heat of hydration
- Toughness
- Volume stability
- Long life in severe environments

Note: *according to the ACI definition, durability under severe environmental conditions is an optional, not a mandatory requirement for HPC.*

"Ultra High Performance Concrete" is nothing but the higher version of the above.

Particle Packing Theory & Its use in design of UHPC

A concrete mix may be considered a pack of aggregate particles in a matrix of cement paste. The packing of aggregate particles comprises of aggregates of smaller than 75 µm (aggregate powder), 75 µm – 5 mm (fine aggregate), and 5 mm – 40 mm (coarse aggregate). Since the matrix of cement paste is more expensive than aggregate, maximizing the packing density of aggregate particles is generally considered a good strategy both to reduce cost of concrete production and to support sustainable development as less amount of cement paste is required to fill the voids within the aggregate particles. Packing density of aggregate particles can be maximized by proper proportioning the aggregate particles of various sizes (that is to determine the particle size distribution of aggre¬gate particles which gives the highest packing density, which may be con¬trolled by fine to total aggregate ratio) and by widening the particle size range of aggregate particles (such as with the inclusion of powder content of size smaller than 75 µm).

The packing of an aggregate for concrete is the degree of how good the solid particles of the aggregate measured in terms of 'packing density', which is defined as the ratio of the solid volume of the aggregate particles to the bulk volume occupied by the aggregate, as given by:

$$\text{Packing Density } (Ø) = \frac{\text{Solid Volume}}{\text{Total Volume}}$$

$$Ø = \frac{V_s}{V_t} = \frac{V_s}{V_s + V_v} = 1-e$$

Continuous approach assumes that all possible sizes are present in the particle distribution system, that is, discrete approach having adjacent size classes ratios that approach 1:1 and no gaps exist between size classes. The fundamental work of Féret, Fuller showed that the packing of concrete aggregates is affecting the properties of the produced concrete. Both Féret as well as Fuller and Thomsen concluded that the continuous grading of the composed concrete mixture can help to improve the concrete properties. Féret demonstrated that the maximum strength is attained when the porosityof the granular structure is minimal. In 1907 Fuller and Thomson proposed the gradation curves for maximum density, which is well known as Fuller's "ideal" curve. It is described by a simple equation:

CPFT = (d / D)n100

According to the Modified Andressen model, CPFT □{(d □□d0) / (D□□d)}q100

Where,

CPFT = the cumulative (volume) percent finer than,

d = the particle size,

d0 = the minimum particle size of distribution,

D = the maximum particle size, and

q = the distribution coefficient or exponent.

The exponent, q, in the Andressen equation could be varied from 0.21 to 0.37, depending upon the various workability requirements. If the exponent increases, it means an increase of the coarse materials, and if it decreases, the amount of the fine materials is increased. The exponent value, q, gives the indication of the finer fraction that could be accommodated in the mixture. As the water demand and water holing capacity of the mixture is controlled by the volume of fines, this exponent gives a reasonable basis for choosing the amount of water and rheology modifying agents like superplasticiser to be added to the mixture.

The exponent value q = 0.25 to 0.3 may be taken for high performance concrete and conventional concretes depending compacting concretes, q < 0.23 may be taken, and for roller compacted concrete, q > 0.32 may be taken.

Our study on The UHPC Self Compacting Concrete

Our team undertook a study at our Dadri unit Concrete Lab. M100 grade of concrete using the locally available materials was the basis and accordingly on basis of the properties of Cement, Aggregates and the Admixtures a mix design was prepared and a series of trials were carried out.

Scope

The scope of study was following:

a) Can UHPC SCC be achieved using locally available materials?

b) What is the effect of fines and microfines on the Fresh and Hardened State Concrete?

c) What are the various combinations possible of admixtures, Fines and Microfines and their dosage?

d) What are the effects of different microfines on the Concrete mass?

e) What are the optimum W/C ratio and the optimization of the structure of mix design?

Methodology

Keeping above points into consideration, a mix design accordingly was prepared with the assumption that water available for the hydration will be limited and the same water in the fresh state shall also contribute into the workability and other rheological properties. The first objective was to set the mix design to achieve 100MPa strength and then adopt the optimization/restructuring cycle. To second and third point a/a the combined gradation curve of the Concrete Mix was

Table 1: Mix Design

Cement	484 Kgs per Cum	20mm passing	100%	A/C Ration	2.453
Alccofine 1203	66 Kgs per Cum	600μ passing	50%	W/C Ratio	0.255
Fine Aggregate	513 Kgs per Cum	Cement Type	PPC Dadri Unit	S/A Ratio	0.38
Coarse Aggregate - I	418 Kgs per Cum	Coarse Aggregates	Crushed	% Alccofine Content	12%
Coarse Aggregate - II	418 Kgs per Cum	Fine Aggregates	River	% Admixture Dosage	1.56%
Admixture PC Based	8.6 Liter per Cum			% VMA Dosage	0.36%
VMA Glennium	2 Liter per Cum				
Water	140 Liter per Cum				

prepared and optimized and a balancing between fines and microfines was set. The cement used was Ambuja Cement which was PPC, the source of coarse aggregates was Haridwar, and Admixture was Polycarboxylic (PC) based with Viscosity Modifying Agent (VMA). In different trials two microfines viz. GGBS (Alccofine 1203), Silica fume and their combination were studied in the first cycle.

Six different set of trials were conducted as per following combinations:

a) A base design having no microfine but only admixture and VMA

b) Mix design having 100% Alccofine 1203

c) Mix Design with 100% Silicafume

d) Mix Design with 70% Alccofine 1203 and 30% Silicafume

e) Mix Design with 60% Alccofine 1203 and 40% Silicafume

f) Mix Design with 50% Alccofine 1203 and 50% Silicafume

While mobilizing the binding character of Cement and pozzolana the density of the mass was also to be duly enhanced to ensure better packing

The Concrete Mix Design:

The concrete mix design was done for being UHPC of Self Compacting Concrete with two hours workability retention with initial flow on flow table of 700mm and "V" funnel flow in 5Secs and collapse slump after 2 hours. The W/C ratio was kept at 0.24 with 12% Micro fines and 1.56% PC and 0.36% of VMA.

The first objective was to set a benchmark of 100MPa achievement with the mix design to enable us to optimize for enhancement of the strength. The second objective in the line was to achieve the target mean strength, for this case it was kept at 112MPa, as per table 1:

Results obtained (Cycle 1)

In all the trials, the objectives related with the fresh state were achieved on flow table, "V" funnel and "U" tube flow tests as per EFNARC guidelines (Please refer table 1)

Figure 1: Testing of SCC Concrete

Table 2: Workability in I Trials Cycle

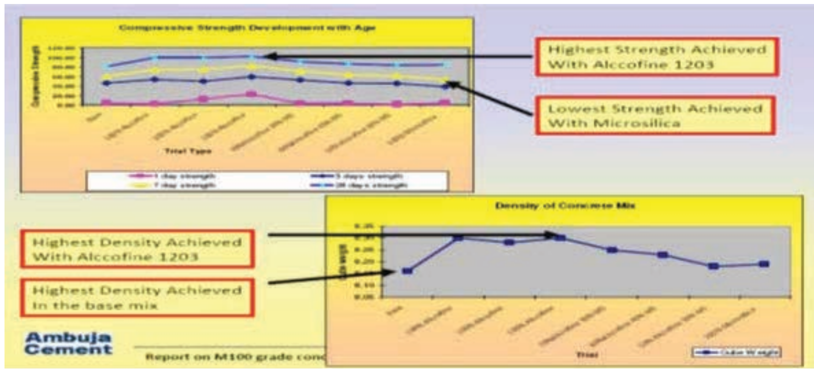
Trial No.	Grade of concrete	Trial Type	Trial with Admixture	SCC Parameters			
				Slump Flow		V Funnel Flow	"U" Tube flow
				T50	Final		
1	M100	Base	PC	10 Sec	600mm	20 Sec	H1 ≠ H2
2	M100	100% Alccofine	PC	6 Sec	730mm	9 Sec	H1 = H2
3	M100	100% Alccofine	PC	6 Sec	730mm	8 Sec	H1 = H2
4	M100	100% Alccofine	PC	5 Sec	740mm	8 Sec	H1 = H2
5	M100	70%Alccofine 30% MS	PC	6 Sec	700mm	8 Sec	H1 = H2
6	M100	60%Alccofine 40% MS	PC	7 Sec	700mm	9 Sec	H1 = H2
7	M100	50% Alccofine 50% MS	PC	7 Sec	680mm	9 Sec	H1 = H2
8	M100	100% Silicafume	PC	8 Sec	650mm	10 Sec	H1 ≠ H2

At the same time in the cycle as evident from results in the table 2 as under, it was only 100% Alccofine 1203 dosage which could attain magical strength figure of even 100 MPa.

Table 3:- Strength achieved in I Trials Cycle

Trial No.	Grade of concrete	Trial No.	Strength (Mpa)			Average Weight of Cube
			3 Day	7 Day	28 Day	
1	M100	Base	45.55	59.85	80.23	8.16
2	M100	100% Alccofine	52.87	73.8	99	8.3
3	M100	100% Alccofine	49.2	74.4	99	8.28
4	M100	100% Alccofine	58.5	81.5	101	8.3
5	M100	70%Alccofine 30% MS	51.75	70.85	90.1	8.25
6	M100	60%Alccofine 40% MS	45.9	63.22	85.6	8.23
7	M100	50% Alccofine 50% MS	45	60.08	82.35	8.18
8	M100	100% Silicafume	38.25	53.25	84.15	8.19

Batch Optimization and Results Obtained (Cycle 2):



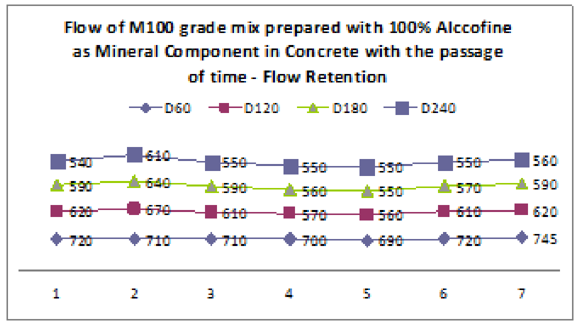
There were following changes observed on the fresh and hardened Concrete

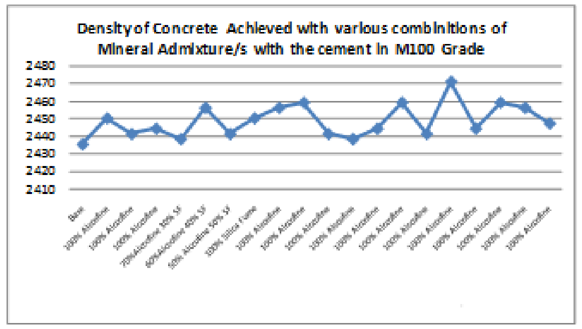
a) The slump was collapse after 2 hours

b) Initial flow was 730mm

c) The average of three cube strength with the age increased vis – a – vis that in Cycle No. 1 were as under

i)	3days strength	=	75.24 MPa (58.50 MPa in Cycle 1)
ii)	7days strength	=	92.67 MPa (81.50 MPa in Cycle 1)
iii)	28days strength	=	115.27 MPa (101 MPa in Cycle 1)





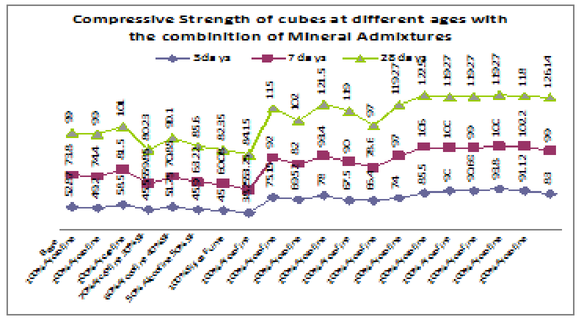


Figure 3: NDT testing of the cubes

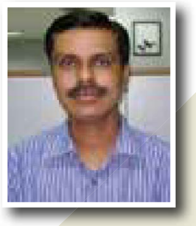
Therefore it could be said that in this optimization this optimization cycle even M100 Grade was achieved.

Conclusions

- High density of the mix was achieved and subsequently higher packing
- Cube failure pattern was dumb bell showing aggregate crushing dominantly
- The trial has established compatibility of PPC and Alccofine to act simultaneously in the mix.
- Alccofine was used as cement substitute and since fly ash was already present in PPC, no further addition was possible and hence not done.
- As far as cement is concerned, it can be established that even strength of 100MPa with Ambuja PPC is now possible.
- The trial was made with the locally available materials and so their capability in a concrete mix was also established.

Reference

1. Properties of Concrete (Fourth Edition) by A.M.Neville, Pearson Education
2. Concrete Technology by A.M.Neville & J.J.Brooks, Pearson Education
3. ACI Recommendations
4. Brochures on Alccofine 1203
5. Various literatures printed by Ambuja Cements Ltd. On Concrete Technology.
6. EFNARC Guidelines
7. NAN SU Method of SCC Mix Design
8. Review of Particle Packing Theories Used For Concrete Mix Proportioning, Mangulkar M. N., Dr. Jamkar S.S., International Journal Of Scientific & Engineering Research, Volume 4, Issue 5, May-2013
9. Applying Theories of Particle Packing and Rheology to Concrete for Sustainable Development, Vivian Wong Department of Civil Engineering, The University of Hong Kong, Hong Kong, China faiyin@hku.hk, Ka Wai Chan Department of Civil Engineering, The University of Hong Kong, Hong Kong, China kwchan84@hku.hk, Albert Kwok Hung Kwan Department of Civil Engineering, The University of Hong Kong, Hong Kong, China khkwan@hku.hk



Author

Mr. Rahul Mathur is the Zonal Head, South Rajasthan in Technical Services, Ambuja Cements Ltd., Udaipur with experience of 22 years in the field of Cement and Concrete Technology. He worked for the design calculations and optimizations of M100 grade SCC Mix Design.

Modular Curing Solution: Structural Vertical Members

Aditya Dar

Abstract

The traditional process of curing concrete is cumbersome, requires extensive labour work and leads to significant quantities of water loss.

Any cement concrete product or structure has to go through a curing process when the product or structure gains strength. The process of curing is done mainly with water. The chemical action between cement and water helps in hardening of concrete.

The present paper deals with a case study of a RCC retaining wall structure can be produced by using other means of Curing like Modular curing Solution. In this technique Plastic sheet used on site for curing of Retaining wall.

Introduction & Objective

Traditionally, curing is done by pouring or spraying water on concrete or mortar surfaces for an adequate period of time. Water has to be continuously replenished as and when it evaporates due to high temperature and low humidity. If the water dries out the strength of the concrete structure or surface will be impacted.

On Vertical surfaces such as Columns, Retaining walls etc, curing is done by sprinkling of water or by using wet jute bags on the exposed surface. This is done by manually and several times in a day.

Typically, labourers constantly sprinkling water on vertical surface to keep Concrete surface wet. On vertical surfaces that cannot hold water, labourers spray water several times during the day for several days.

Need for Alternative curing Solution:

- In hot and arid environmental that usually exists in our country there is a critical need to prevent loss of water from the vertical surface
- Challenge to make wet surface up to 7 days
- Sprinkling of water evaporate after few hours on vertical surface
- Labors not done effectively curing on below foundation in critical situation
- Huge amount of water is wasted for curing in vertical Members
- Concrete of Vertical Members are very importance under shear criteria
- Many times curing of Retaining wall of both sides is practically not possible due to safety aspects in Deep excavation.
- Improper curing of vertical members lead to poor strength of Concrete

Alternate Curing Method for Vertical Members Developed by Technical Services Engineer (Ambuja Cement Ltd.)

- Modular curing solution is a plastic sheet that prevent water losses Against high wind velocities, low humidity and high ambient temperatures & sufficient to protect against such environmental effect for Vertical Members like Retaining wall & RCC Column
- It also reflect against sun rays and through that water absorption from Concrete can be reduced
- Single Vertical Sheet of size 8ft (Height) X 6ft (Width) made with Velcro attachment has design and stick with each other. (photo)
- According to our need we can design various sizes of sheets for covering concrete surface

Indian Standard (IS 456) Code Specification of Modular Curing

Membrane Curing

Approved curing compounds may be used in lieu of moist curing with the permission of the engineer-in-charge. Sch compounds shall be applied to all exposed surfaces of the concrete as soon as possible after the concrete has set. Impermeable membranes such as polyethylene sheeting covering closely the concrete surface may also be used to provide effective barrier against evaporation.

Use of Modular Curing Solution in Vertical Members

- We have used Modular curing solution for Vertical Retaining wall at IHB Site in Ahmedabad
- Customer Mr. Bhavin Shah have also provided necessary support during implementation
- Vertical Retaining wall has been covered from both side front & back with Membrane.

Front View

Back View

After 7 days of removal dampness observed on retaining wall

Challenges for Vertical Modular Curing Solution. The challenges in vertical Modular Curing Solution are as give below,

- During laying of Vertical MCS no further construction activities will start up to 7 days
- In back side of Retaining wall necessary to take extra safety against land sliding
- Up to 7 days earth filling out side & inside wall for below ground level work is also not possible
- Stable foundation needed during laying of Vertical MCS

Conclusion

Vertical Modular curing solution is effective and proven technique for curing of Retaining wall and Column. Ambuja Cements Technical Team has provided this type of Solution to more than 100 nos. of sites in various part of Gujarat through our Laboratories.

Acknowledgements & References

- IS 456 : 2000 clause no. 13.5.2
- Guidance from senior technical team of ACL
- Active support for field application by owner of the site
- Involvement of our Dealer Sh. Jaydeep Shah from M/S Rupamkrupa Traders, Ahmedabad
- Support from ACL's Engineer Mr. Krutarth Pathak, Mr. Khanjan Shah & the Lab. technicians

Author

Mr. Aditya Dar is a Practicing Civil Engineer (B.E. Civil) having total experience of more than 20 years in the field of Construction. He has worked as a Project Head & Consultant for Industrial & Residential Projects at Ahmedabad.

Quality Control and Mix Design Practice in India and Sustainable Concrete

B. Bhattacharjee

In this article, statistical quality control (SQC) used for concrete production, followed globally, is highlighted. The lack of such practice in bulk of concrete construction in India and its implication on wastage of cement is discussed. One of the common practice in India is to prescribe certified mix proportion for concrete. It is highlighted that such conservative practice is detrimental to development of concrete technology in the country. Further, it is pointed out that adoption of concrete as a major product rather than cement, mechanization, adoption of SQC and plant based control rather than prescriptive approach to concrete production will go a long way towards sustainable concrete in India.

Concrete Quality Control Practice in India

In India, formal structural concrete is produced and being used since the time of 'Gateway of India' i.e., the first RCC structure constructed in the decade of 1920s. Technology of production and casting of concrete, as well as, material science of concrete has evolved exponentially since then. Modern concrete is extremely versatile in rheological performances in fresh state also in mechanical and durability performances in hardened state. Industrialized production of concrete structural elements is also possible with high level of accuracy and compliance to specification through appropriate statistical quality control (SQC). India is the second largest producer and consumer of cement and hence also the second largest consumer of concrete as a nation; but, production technology and modern scientific quality control system is yet to be adopted in a large scale across the country. While in case of infrastructure projects e.g., bridges and dams, modern construction practices are often adopted, however in buildings such practices are seldom applied [1]. Sustainable concrete requires minimizing the resource usage for specified performance and that demands adoption of SQC system [2,3].

Quality control of any production system has three steps, a) forward control, b) immediate control and c) retrospective control, the last one involves quality monitoring. Internationally, in many countries, as a mandatory practice, these steps are applied to ready-mix concrete (RMC) production and production at pre-cast plant as well [4,5]. Forward control encompasses (i) testing of all ingredients, i.e., cement, aggregates, admixtures and water etc., at plant. This is to ensure that the material satisfy the required specifications within limits and do not contribute unnecessarily to undue large variation in concrete properties. (ii) Proportioning of mix specific to the material for specified performances. (iii) Maintenance of mixer machines, batching plant etc., (iv) periodic calibration check of the load cells of the weighing machine and dispenser for admixtures etc., i.e., all verifications and checks prior to actual concrete production. Immediate control refers to testing during production e.g., slump measurement at plant and also slump loss at delivery point, visual observation etc. The retrospective control is performed through SQC using Control (Shewhart) Chart and CUSUM method. The concrete differs from other material in this case as specification of concrete is associated with 28 days strength, hence application of SQC can delay the corrective measures as outcome would be known only after testing at 28 days. To overcome this short coming, accelerated curing of concrete is adopted and 28 days strength is estimated from accelerated strength test through established correlation. The correlation is concrete specific and is again monitored continuously, and; corrections are applied in case of any deviations from used correlation. CUSUM method is generally adopted for retrospective control of RMC in many countries. The details of the procedure are available in textbooks and literature [4-7]. To illustrate some of the aspects of CUSUM method, it is presented in the following paragraph.

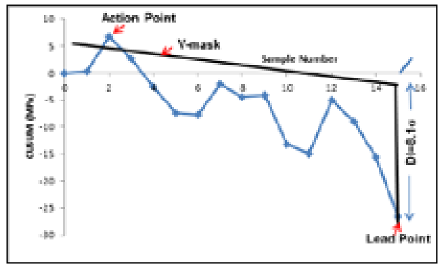


Figure 1: Typical CUSUM plot for mean

CUSUM method in case of concrete is applied to (i) mean, (ii) range as a measure of standard deviation and also to (iii) correlation between predicted strength from accelerated test and actual 28 day strength. Test on concrete cubes subjected to accelerated-curing is performed say at 2 or 3 day age. The 28 days compressive strength is then predicted from the strength obtained through the accelerated test using the above correlation. In case of CUSUM for mean, the deviation of predicted strength from target mean strength is calculated and cumulated from first sample, continuously. The trend of this cumulative sum or CUSUM is plotted against sample number as shown in Figure 1. An upward trend indicates Mean strength of the produced concrete is higher than target mean strength and is probably uneconomical. When the CUSUM trend swings around zero or X axis the concrete is designed correctly and no corrections are required. A downward trend indicates (as shown in Figure 1) that the actual concrete produced possibly does not satisfy the target mean strength requirement and proportions need to be corrected to obtain the desired strength. To identify whether trend exhibited at a particular sample point warrants correction or simply can be attributed to random occurrences, a V-mask as shown (part only) in the Figure 1 is used. The truncated V-mask is characterized by decision interval DI=8.1σ, σ being the established standard deviation (or may be estimated standard deviation 's' also) of strength, and; the gradient line with its slope as σ/6 (s/6) for mean and correlation. On obtaining a new sample data corresponding CUSUM value is calculated and plotted on the CUSUM plot and becomes the lead point as shown. The centre point of V-mask is placed on the lead point. As long as all the previous CUSUM values remain within the boundary of the truncated V-mask, no action is required. The CUSUM plot thus continuously gets elongated. When for any lead point, the CUSUM plot lays outside the boundary of the mask as shown for 15th data, it indicates a systematic deviation, as opposed to random variation, hence, correction must be applied to the mix proportions and CUSUM plot is restarted from 0 again, shown in Figure 1 from sample 15, for the modified mix. It is apparent that till 14th data as lead point no action was warranted. A simple algorithm as given below may come handy in excel spread sheet adoption of this method. Let qst be the CUSUM value at tth data point, then for qst-qs(t-n)<0, n=1,2,….(t-1) for majority of n in general, there is a decreasing trend for strength and; for qst-qs(t-n)>0, n=1,2,….n, for majority of n in general, the trend is an increasing one. For former case of decreasing trend, (qst+8.1σ+nσ/6) <qs(t-n) n=1,2,….t at any n=N indicates a systematic decrease in mean strength. The data point at N represents the action point; t-N = run length = r (say). The corresponding correction in mean strength ∆fm= {DI+r×G}/r = 8.1σ/r+σ/6. The mix proportions then are to be modified for a target mean strength, increased by ∆fm. Similar exercise can be performed for correlation and range i.e., standard deviation also. Details of this method are readily available in text books [4-9]. One may have to apply such a correction either for strength or standard deviation for every 15 or 30 data points, thus determination of mix proportions for a specified grade of concrete in a project is not a one time job rather dynamic with frequent changes. Such a dynamic SQC can only be applied by doing mix proportioning at site and plant laboratory and not in any remote laboratory. A survey on long term strength data from a number of RMC plants in Delhi NCR was reported by author as co-author in an earlier paper [8]. None of the RMC plants were using CUSUM method and systematic SQC in totality. It was demonstrated through a mock exercise of CUSUM method that many of the plants were wasting cements as strength were higher than the target strength required. None of the plants were using accelerated test facilities. To the best of author's knowledge, situation in the country is no better even now and systematic SQC is not adopted in most of the concrete construction projects. Rather mix proportion is considered static and proportions are decided on the basis of mix design carried out at institutional laboratory once only in the beginning. Thus nationwide there may be serious wastage of cement that can be avoided by adoption of systematic SQC and mix proportioning at site/ plant as discussed above.

Mix Design Practice

Often proportions of concrete mix in construction projects in India is done by mix design carried out at institutional or research laboratories e.g., IITs, NITs or Government research laboratories etc. with small quantity of supplied material required for tests and for making some cubes. The results of the same however, is used for a long time in the project possibly for whole project duration spanning over years, even though the material might have changed. For example, a recent request came from a reputed construction organization, for consultancy job at IIT Delhi, for testing materials for source approval and carrying out mix design for M25, M30, M35 and M40 and samples were also said to be supplied. Additionally, minimum cement contents were also specified as 330 kg/m3, 340 kg/m3, 350 kg/m3 and 360 kg/m3 respectively for M25, M30, M35 and M40 respectively. Total material supplied included 4 bags of coarse aggregates, 2 bags of M-sand; cement 2 bags each from 3 manufacturers, concrete construction quality water 5 litres and admixture of a specific make, 5 litres. The project is a large building infrastructure construction project involving office buildings in a megacity. Two interesting observations can be made from such a request. First, the total quantity of material supplied is just good enough for about maximum 9-10 cubes per grade for each brand of cement. Mix proportions decided on the basis of such small sample size is expected to satisfy the concrete specifications required over the long period of project, for a large mega project, in spite of the fact that material from the same source, even though likely to satisfy the limits, may induce significant change in fresh and strength properties of concrete. The second observation concerns the minimum cement content specified in the request. Minimum grade of concrete specified is M25, thus it is apparent that the exposure considered is moderate. Specified cement content is good 10 kg/m3 more than that required for durability requirement in IS: 456-2000. This request for mix design is not isolated one; many reputed organizations adopt this kind of practice, more so without SQC mentioned earlier. The result is either wastage of cement or non- adherence to strength requirement.

Cement is produced from natural raw material with minimal processing except that the raw material mix fed to the plant is made homogeneous as much as possible, yet it is the only factory produced material in the concrete. Even then, for cement of the same brand both fresh property and strength of concrete is likely to vary from time to time and lot to lot. Systematic controlled aggregate production has just begun in India. Aggregate from the same source but collected at different times are likely to exhibit different packing characteristic due to variation in shape, and grading. Aggregates obtained at different times are likely to affect the concrete strength in varying manner due to variation in size, texture, elastic and surface energy properties. This variation is likely to be more for less mechanized production. Thus properties of concrete obtained on the basis of single time test cannot be extrapolated for long term use. Hence overall SQC for concrete production is desirable rather than single time initial mix design and continuing with it for the whole project.

Mix design is done to obtain the proportion of constituents that would ensure concrete of properties complying with certain specifications, economically. Thus ideally speaking mix design should have been handled as an optimization problem for cost minimization, with greater than equal to type of constraints satisfying the specifications such as slump≥specified value, strength≥target mean strength. However, well defined and unique mathematical relationships relating strength, service life or slump to proportions of ingredients of concrete are not available. This is because materials used are largely natural and not processed; variability is large and thus difficult to idealize for modeling. More than 50 empirical relationships relating to slump and to factors affecting, are reported by Popovics, [10] hence not unique and not universally applicable. Similarly, there is infinite number of curves relating strength 'f' to water to cement ratio (W/C); e.g. those recommended in DOE mix design procedure and is again not unique [11]. The strength f at any W/C can be empirically related to strength f0.5 at W/C =0.5, through Abraham's law using the data of DOE curves as:

$$f = K_1 \times K_2^{W/C} \qquad .....(1)$$

where:

$$K_1 = \left[58.11 \times \ln f_{0.5} - 60.47\right]$$

$$K_2 = \left[\frac{f_{0.5}}{540.76} - \frac{1}{6371.84}\right]$$

However, there are infinite numbers of $f_{0.5}$ depending on other ingredients. Change in ingredients with time would results in change of $f_{0.5}$ and in turn would cause change in f, the change Δf would be higher at lower W/C and can be of the order 10-15% of "f" for $\Delta f_{0.5}=0.1f_{0.5}$..

There are many methods of mix proportioning and, is not unique again. Mix design is not done using fundamental mathematical models, rather is performed from simple empirical, geographical region based, charts, tables or equations, although principle and steps involved may be similar in many methods. Calculations involved are very simple and may not require more than 10 minutes when done using spread sheet in computer by a person familiar with the component ingredients. Laboratory time required rather can be high as number of trial casting and repeat tests may be involved. Thus more of physical effort than mental one, and; experience plays a strong role in mix design. This is recognized in recent IS 10260:2009; according to the recommendation prescribed in this code, the starting W/C is decided either from durability criteria or experience. Hence mix design of concrete is both art and science and can be easily done fast with lesser trials by qualified and experienced person/team in laboratories equipped with simple concrete testing facility meant for preparing cubes and testing them for compliance and acceptance. Such laboratories are readily available at RMC/site plants. There is hardly any research involved in day to day mix design and hence need not be done in remote institutional laboratories. On the other hand plant laboratories shall be capable of doing mix design and modifying the same as and when required on a regular basis as governed by CUSUM method of retrospective control of SQC. This will ensure cement saving and production of appropriate quality of concrete. This is the practice adopted in most of the nations where concrete technology has advanced to an engineered-material level.

Quality of Concrete and Sustainability

Role of quality control in reducing carbon emission, reducing natural resource wastage and thus their depletion, has been elaborated in earlier papers [1] and needs no further elaboration at this stage. Mechanized and industrialized production of concrete has a major role in this regard as overall variation can be controlled to a significantly lower level of standard deviation by controlling variation of individual component factors in the processes of batching and mixing etc., through automated sensing and computer controlled production. In countries where concrete technology is significantly advanced compared to India, cement is sold less as a product compared to concrete. The cement producing companies often themselves produce aggregate from open cast mines or quarries using mechanized production method; make concrete, and; market concrete as a major product rather than cement. To a civil or structural engineer concrete is the material and not cement. Quality of concrete is more important rather than the mix used in it. Thus prescription of proportion and certification of mix is rather detrimental to the innovation and development of concrete. The practice of carrying out mix design of concrete at remote laboratories therefore is doing a dis-service to the development of concrete construction practices in India and sustainability in general, therefore shall be discontinued. A survey of investigations of rebar-corrosion distressed buildings in northern and central India published earlier revealed that internal chloride from ingredients; low cover and poor quality of concrete were the main causes

of early distress exhibited in a majority of structures [12]. For many of these structures mix designs were carried out remotely and certified, in spite of that, early distress became evident.

The concrete today is quite different than yesteryears. Newer cements and cement combinations are being adopted. Bureau of Indian standard (BIS) has already adopted a code for composite cements with OPC, Fly ash and GGBFS in addition earlier cement codes, Euro codes EN 197-1:2000, recommends use of 27 combinations of cement and cementitious combinations, LC3 cement and Magnesia based cement, geo-polymers are other binder system those are being considered and adopted at various level. Other ingredients and their usage are also going through paradigm shift. Thus performance compliance of concrete shall be judged through various acceptance methods using appropriate criteria rather than compliance prescription guidelines for ingredients and mix except in some special cases. Beside cube test for strength compliance, some Indian projects had already adopted DIN 1048 part 5 (BS_EN 12390-8) water permeability through depth of penetration test for durability compliance. In-situ test for concrete performance for durability is already considered and may be the next step.

RMC plants are now there in many small and medium sized towns of the country. Adoption of total SQC and mix design and control at plant will go a long way to serve the cause of sustainability by minimizing the resource wastage.

References

1. BHATTACHARJEE, B. "Sustainability Of Concrete In Indian Context" Indian Concrete Journal. 2010, Vol 84 No.07. pp.45-51.
2. BHATTACHARJEE, B. Sustainability Performance Index for Concrete. International Concrete Sustainability Conference August 9-11, 2011-Boston, Ma, USA. http://www.nrmcaevents.org
3. BHATTACHARJEE, B. Performance Specifications Of Concrete With Reference To Sustainability. National Seminar on Performance Specification of Concrete, New Delhi, India, September 24, 2011. ICI New Delhi Centre.
4. DEWAR, J.D. and ANDERSON, R. Manual of Ready Mixed Concrete, Blackie and Son Ltd., Glasgow and London. 1988
5. DAY, K. W. Concrete Mix Design, Quality Control and Specification, Taylor & Francis, 2006
6. NEVILLE, A.M. and BROOKS, J. J. Concrete Technology, ELBS .1990
7. NEWMAN, J. and CHOO, BAN SANG. Advanced Concrete Technology-Testing And Quality, Elsevier 2003
8. SARKAR, D. and BHATTACHARJEE, B. Quality Monitoring of Ready Mixed Concrete Using Cusum System. Indian Concrete Journal, 2003, Vol. 77 No.5 pp. 10601065.
9. SARKAR, D. and BHATTACHARJEE, B. Design And Application Of Multivariate CUSUM for Quality Monitoring Of Ready Mixed Concrete. International Journal of Quality Engineering and Technology. 2014, Vol. 4 -No.2. pp.161-179.
10. POPOVICS. S., Fundamentals Of Portland Cement Concrete: A Quantitative Approach Vol 1 Fresh Concrete. John Wiley & Sons.1982
11. SP 23 Hand Book Of Concrete Mix Design. Bureau of Indian Standard, 1990.
12. BHATTACHARJEE, B., RCC structures distressed due to rebar corrosion - some case studies. Civil Engineering Today (Journal of ASCE - India Section). 2005, Vol. 3. pp. 3-12

Author

Professor Bishwajit Bhattacharjee is working with the Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi (India). His research interests pertain to the domains of cement and concrete technology, building science, sustainable construction, and health monitoring of structures. His publications in these areas are well cited. He is also a recipient of the Indian Concrete Institute's Life Time Achievement Award.

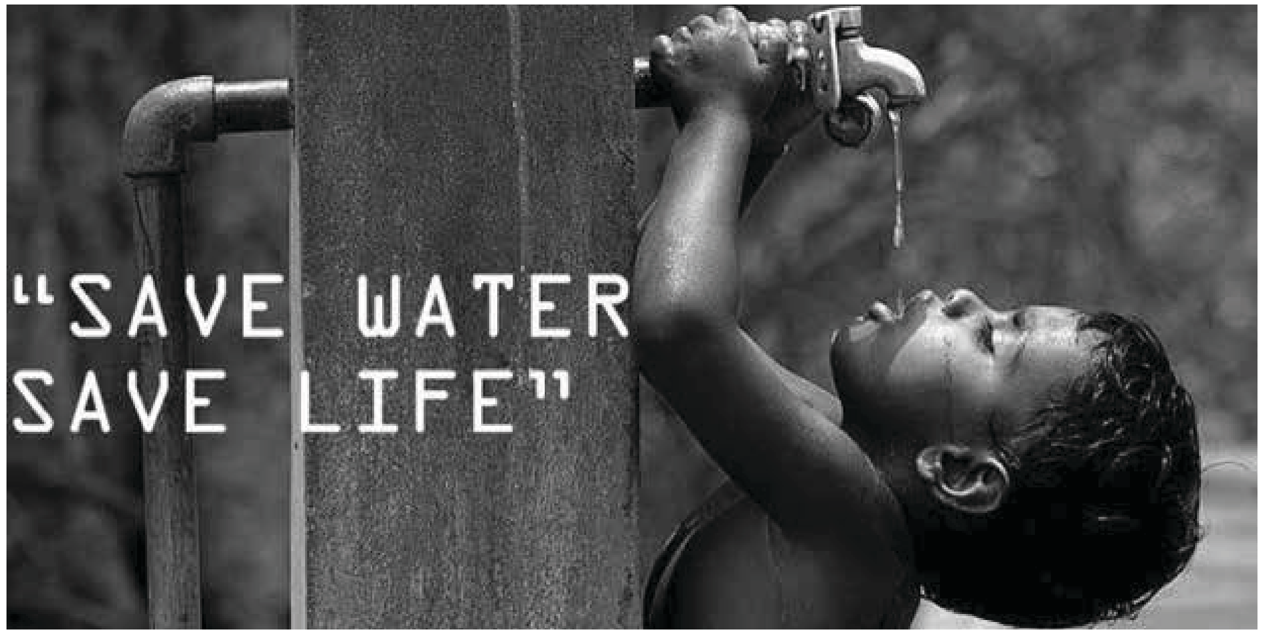
Note

This paper was first published in The Indian Concrete Journal, July 2016, Vol. 90, No. 7, pp.14-18 and is reprinted here for wider dissemination, here in Ambuja Technical Journal Vol.3, January 2017.

The paper Titled "Comparison of Strength between Retempered Concrete of two Different Grades" A.R. Pethkar and G.K. Deshmukh, published in The Indian Concrete Journal, September 2016, Vol. 90, No. 9, pp.22-24, reprinted in Ambuja Technical Journal Vol.2, October 2016 on page: 17-19.

Save water - Save Life

Medhekar Prakash



Abstract

Earth 70 % area is covered by water; still the whole world is thirsty for want of drinking water today is a fact. Only 3% natural sources of water is potable while all other has to be treated. Today's world population is around 7 billion, will reach to 9 billion by year 2050. That time around 5 billion people will be in struggle of pure water. Urbanization is a continuous process in future which cannot be stopped by anyone. Cities will be more crowded by people & their water demands will be increasing. Like other material we cannot create water for which we are wholly depends on nature. Due to the global warming the natural cycle of seasons has changed. Rainfall intensity has decreased than previous years. Extraction of more water from earth than required has reduced subsoil water level drastically. Water is getting contaminated by our discharges. Every day many children are causing their death just because of the diseases related to contaminated water.

Water will be more costly than fuel if not saved properly. We must all find all the means how the valuable water can be saved. Nature is sufficient for everybody's need but not for everybody's greed. Unplanned development is a root cause of global warming causing great disaster in future.

Introduction

Construction sector is 2nd largest in India & it size close to US $ 12 Billion and around growth about 20% per annum next to agriculture one. Both the sectors needs tremendous amount of water. Our basic need is food, clothing & shelter. Shelter is being provided by our construction industry. Today two more things are added to it as fresh air & water. We have ample natural air but we ourselves are responsible for its pollution. We cannot create water but at least can save the available one. We are totally depending on nature for our water need. In fact we are preying super natural power every year for the same. To maintain environmental balance concept of Green Building has taken place around the world. With the help we can provide safe and healthy shelter for the people protecting our environment. Creating more green buildings in future we can be able to conserve natural resources, increase energy efficiency.

Leed

The Leadership in Energy and Environmental Design (LEED) Green Building rating system TM encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally. Architects, real estate professionals, interior designers,

land scape architects, construction managers, developers, builders, government officials all use LEED to help transform the built environment sustainably. LEED is in progress 50 countries including Canada, Brazil Mexico & India.

Green Building

For Green Building construction more focus is given for site planning, water management, indoor environmental quality, material use & energy conservation. LEED gives rating depending upon sites water efficiency, energy &atmosphere, material & resources, indoor environmental quality, innovative design process.

Figure 1: Green Building

McKINSEY REPORT: Mckinsey Global Institute (USA) report dated April 2010 says up to year 2030 growth of urbanization will increase . People from villages will move to cities. In India 68 cities will have population more than one millions. 13 cities population more than 4 millions. Mumbai & Delhi will become Mega Cities. Indian urban population will may reach up to 590 million by 2030. This all will lead to increase in water demand in urban areas.

Strategic Foresight Group Report

June 2008, Strategic Foresight Group Mumbai and United Nations Global Compact had co-hosted a conference on importance of water security. Conference was attended by experts from 25 countries in Mumbai. In this conference importance of water security was highlighted. It was not the first time that anyone predicted future water crisis but it was a significant occasion when linkage between water & human security was discussed and urgent action was called for. Predictions says countries like India, Pakistan, Bangladesh, China may disturb their inter relation just because due to water distribution. To keep world peace , distribution of water by proper management is must among all the neighborhood countries. Due to the world global warming temperature in Himalayan region is **increasing day by day causing melting of** ice at early stage. Due to change of this natural climatic condition, river flow will be reduced substantially around 250 Billion cubic meters at the end of 20 years. By year 2050 grain production in our country will be reduced by 40 to 50 %.This will turn in to new diseases, political instability, internal crisis in India. To overcome this we must all think seriously from this moment.

Urbanization of Pune City

Pune is one of the fastest developing city in India. Poona present population around 5o lacks. This city is fortunate to get water from four dams like Khadkwasla, Varasgao, Panshet & Temghar. All Pune citizens are getting ample water for their use since longer time. But from last few years city is also facing shortage of water especially during summer time. Due to the world global warming average rainfall in the dam catchment area is found less than expected or required. Presently citizens of Poona is getting more water than the the standard norms 135 lit/ person / day. Presently they may be enjoying it, but in future this will lesser & Yr 2030 as per Mckinsey report considering the forecasted population we may get only 65 lit/ person/day.

Water Saving Methods

We cannot create water but definitely can save it by all means. Increasing population, rapid urbanization, change in lifestyles, all contributing towards rising water demand and wastewater discharges. High percentage of water is being used especially in building toilets. By implementing efficient plumbing systems we can control the excess use of water. Fixtures like water closets, urinals, faucets & shower consumes more water. We can save water by reducing its use, reusing by proper treatment. Recycled treated water can be used for car wash, land scape areas. By controlling water pressure we can save substantial amount of water. In developed countries like Australia, USA, Singapore the fixtures which saves water are labeled by star system like 1 star to 5 star, The more stars, the better water savings. Indian Plumbing Association (IPA) and International Association of Plumbing & mechanical Officials (IAPMO – India) are jointly taking efforts to fix such rating systems in India, This will help us for identifying water efficient fixtures from any market.

Water Saving Fixtures

By use of dual flushing system, sensor taps, low water toilets, aerator taps, waterless urinals etc we can save the water tremendously from our day to day use. Water less urinal is a new concept to our country which is introduced by FALCON water free technologies USA . As compare to our flush urinals this has many more advantages. It is touch free, odor free & bacteria reductive fixture. "Urine odor" primarily results from the reaction of urine with water and air, creating ammonia oxide. Without water, there's no reaction.

How waterless Urinal Work

The main part of water free urinal system is the cartridge, which acts as a drain trap. The cartridge design and use on nonporous materials ensure that all urine passes in to the cartridge and through a unique, biodegradable sealant. The pleasant smelling sealant liquid provides an airtight barrier between the drain and the restroom to prevent odors from escaping. The sealant lasts for the life of the cartridge, so no need to add sealant between cartridge changes. The cartridge also acts as a trap for uric sediment, which could otherwise

contribute to drainage pipe clogging. Each water free urinals saves an average of 1 lacks liters of water each year. It saves energy required for pumping of water as not required. Energy saving helps reduction in Co2 emissions contributing to global warming. The only maintenance is routine cleaning of the fixtures and an easy change of the cartridge approximately after every 10,000 uses. This urinal is labeled as LEED product

Figure 2: Waterless Urinal

Conclusion

Cities are getting crowded more & more in future by increase in population. Population needs water for their lives & hygienic. Lots of cost is required to make water potable for drinking & other utility purpose .Cost for the drinking water may be non affordable in future if we doesn't save it properly. Water saved today can be useful for tomorrow.

Reference

Reports by:--

- Mackinsey Global Institute April 2010.
- Strategic foresight Group June 2008.
- Indian Plumbing Association. Nov 2010.
- Falcon water free technologies USA brochures.

Author

Er Medhekar Prakash - B.E.CIVIL, FIE, FIIBE, FIV, CHARTERED ENGINEER, GOV.REGD.VALUER. He did his graduation in civil engineering from college of engineering Pune Year 1982. He worked India & abroad in various construction fields for more than 30 years. He is a research oriented and written around 150 technical articles in local news paper. He is a chartered engineer and approved valuer. Er Prakash is a fellow member of institute of engineers, bridge engineers and institute of valuers. He is attached as visiting faculty to Project & Construction Management Department MIT College Pune.

Mail: prakash.5956@gmail.com

Mobile :- 9146133793

Rainwater Water Harvesting Solution For Every Roof

Gajendra Godle

Background

Many parts of India receive enough rainfall to have clean and drinkable water throughout the year. However, water management in India woefully lacks the capability to store and distribute water properly. Rapid urbanization has accelerated the demand for water. At the same time, it has also become a chief cause of depleting rainfall and ground water levels. Government machinery is too slow to respond to the mammoth challenge.

It's up to the individual citizens to help themselves. Rooftop rainwater harvesting is one solution that gives the power in the hands of the individual house owners to produce water for their own requirement. Interestingly, a mere100 cm rain in a year on a 100 square feet roof gives full year's drinking and cooking water needs of a 5-people family.

Water Scarcity – A challenge

Route Causes & Facts

Uncertain Rainfall & Change in Rainfall Pattern

In India, the actual rainfall in last decade has shrink in number of rainy days both in case of pre-monsoon & four month period of monsoon. This indicates the increase in the intensity of rainfall with decrease in actual rainfall days which further affects the percolation rate, causing short duration floods in rivers/nallahs.

Dependency on Ground Water resources

The dependency on Ground water for irrigation, drinking & industrial use has increased significantly in past decades as it is the only available & convenient alternative in draught & empty reservoirs. Further this has affected the ground water levels in many parts of the country which has gone down drastically as it is the only alternative.

Whatever we are taking out, not giving back to the nature

Lack of awareness, Unavailability of proper resources, skilled applicators has created the situation of whatever we are taking out, not giving back to the nature.

Depleting Ground Water Levels in India

Ground water levels in some areas are falling at the rate of one meter per year and rising in some other areas at the same rate. The no. of wells and bore wells increased fivefold to more than 175 lakhs during past fifty years. More than 80% of rural and 50% of urban; industrial and irrigation water requirements are met from ground water.

Challenges in Coastal areas

Serious environmental problem to coastal subsurface water systems, due to Global warming-sea level rise, increasing salinity due to sea water intrusion is becoming major problems along coastal regions of India.

Conserving rain water – A solution to self sufficiency

Only Solution is to return back what we take from the ground. "Rain water harvesting" is very effective method which provide self-sufficiency to water Capture rain water, store it and use it - it is as simple as that. Collect the rain water falling on house tops, collection ponds, lakes, open areas with natural grading. Rain water is naturally pure (excepting where it becomes acid rain due to industrial pollution), Ground water could be salty or brackish.

Understanding "Roof Top Rain Water Harvesting"

- Collect water from the rooftop.

- Draw it down from pipes.
- Filter the water.
- Store in a sump or tank for later use.
- Charge the groundwater through a soak pit OR
- Lead the water into a well to increase ground water content.

Benefits of Roof Top Rain water Harvesting

► Economics

- Reduces water bills
- Reduced water demand - water supply utility saves money on treatment and pumping
- Reduces cost of infrastructure necessary for water supply

► Environment

- Energy saved – no pumping of water to our homes
- If water is hard, adding soft rainwater improves water quality
- Improves groundwater situation
- Reduces demand for water at city/ village level

► Benefits to house owners

- Simple, cost-effective, easy to construct and maintain
- Viable in urban and rural areas, slums, low income housing, apartments

In June this year, Ambuja Cement decided to get involved in promoting and installing rainwater harvesting system as an extension of its technical service to the individual house builder (IHB).

The technical service engineers have been providing a unique zero-water curing service during slab casting for over the last 4 years and have helped save 155 million litres of water. Now, the consumer gets the roof rainwater system installed once the roof is completed.

Ambuja has developed new Roof Rainwater Harvesting technology is derived from multiple reference codes, manuals and research reports. Rainwater is collected through channel pipes or gutters made up of PVC or similar materials. A filter is used to remove impurities in the water and the cost of the filter depends on the roof yield. The filtered rain water is then stored in a storage tank and this can be used for drinking and cooking purposes. The surplus water from the storage tank is discharged into a pit for ground water recharge purposes. The average approximate cost of installing the Roof Water Harvesting system in an individual house which includes installation of plumbing, filters, storage tank and percolation pit is around Rs. 40,000/-. (Refer the diagram)

Ambuja Method of Rain Water Harvesting

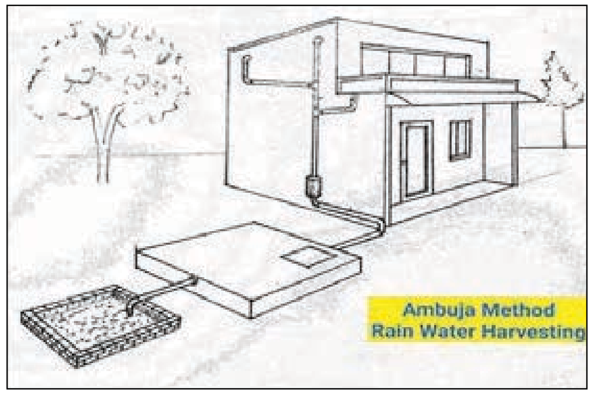


Figure 1: Ambuja Method of Rain Water Harvesting

► Features:

- Scientifically Designed system
- Self-sufficiency for dry period
- Dual facility i.e. Storage & Ground water recharge
- Easy to implement & less maintenance
- Efficient & Effective method
- A small town of 600,000 population has ~ 1600 houses under construction and ~ 71000 existing structures. Rainwater harvesting thus is not only a CSR initiative, it has a greatpotential to provide customize solution to every building structure. Ambuja has spread awareness among the consumers through its network of off-line and digital platforms. Many local administration bodies have joined hands with Ambuja to create awareness and execute the system in small towns.
- Till Nov 2016, Ambuja TS Engineers spread the awareness about this initiative and solution across 425 centres covering ~ 11000 customers who are constructing their houses, trained more than 3500 contractors under the Applicator module resulted in on site implementation of Roof top rain water harvesting system at more than 330 sites. (150 Completed, rest are in Progress). Approximate water conservation per site is around 12.50 mio lit water per annum.

Onsite Implementation Photographs

Figure 2 : Onsite Implementation Photographs

Measuring success

Since its inception the Company has shown great commitment towards water management. It values water immensely, as it is a scarce natural resource. It not only continues to reduce the water footprint its operations, but also promotes responsible water management in partnership with various government and other local stakeholders. Ambuja Cement tracks water withdrawal, consumption, reuse/ recycling and discharge. The Company defines 'Water Balance Index' as the ratio of water credit over water debit at each site. 'Water debit' denotes the total volume of water consumed; and 'water credit' is the summation of the volume of recycled/ reused water, harvested rain water, recharged ground water, water saved through better agro-practices/ techniques (drip, sprinkler, systematic rice intensification), and value-added services. If, the water balance index is greater than one, it indicates a positive water balance. A combination of various water harvesting programs and revolutionary techniques are employed.

"Rainwater Water Harvesting Solution for every Roof"

Author
Gajendra Godle he is currently employed as National Manager for Customer & Influencer Engagement at Ambuja Cements Ltd., Technical Services Department at Corporate Office, Mumbai. Responsible for Customer Engagement initiatives & strategies implementation. Under Sustainable Construction Practices, developed Ambuja Method of Roof Top Rain Water Harvesting module & trained more than 300 TS Engineers, Applicators pan India.

I CAN.

We are initiating question corner wherein professional may ask a question related with construction material / practices / techniques for better implementation on site. The answer will be given by an expert.

You are requested to send your question on email ID: ambuja.technicaljournal@ambujacement.com

Question 1:

Building of 20 storey regular rectangular building, without many cut outs in the slab….

What about the rigid diaphragm action for above mentioned building, how lateral loads shall be shared by the elements in proportion of the stiffness? When to consider this as rigid diaphragm and where to consider this as semi rigid diaphragm?

By Mr. Sumantkumar B. Patel, (Prof in BVM Engg College VVNagar, Gujarat, and also Structural Design Consultant)

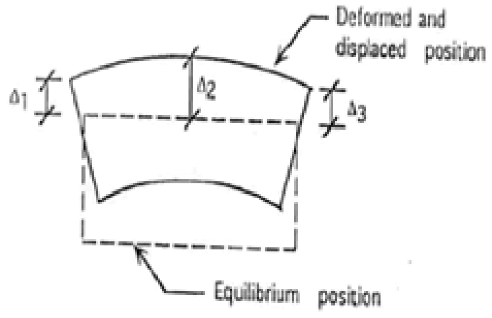
Reply – Mr. Prakash Bajaj, Structural Consultants, Mumbai

Answer 1:

The diaphragm is a horizontal resisting element act as horizontal deep beam that transfer forces between vertical resistance elements. Earlier buildings were analyzed for lateral loads by simply modeling a series of 2D frames and applying nodal loads. Later, with the development of softwares, lateral loads could be automatically generated for a building and these loads could be distributed to the lateral frames in the model.

Rigid Diaphragms

A diaphragm may be considered rigid when its midpoint displacement, under lateral load, is less than twice the average displacement at its ends. They consists of reinforced Concrete slabs, Precast Concrete slabs or Composite Steel Deck. They distribute the horizontal forces to the vertical resisting elements in direct proportion to their relative stiffness. The rigid diaphragm does not deform itself and will cause each vertical element to deflect the same amount. When floor diaphragms are rigid in their own plain in relation to the vertical structural elements that resist the lateral forces, torsion irregularity shall be considered.i.e, they are considered to be capable of distributing torsional and rotational forces. In some cases, however, structural configurations with large spans between lateral resisting elements can invalidate the use of the rigid-floor assumption. For these cases, diaphragm flexibility must be considered in the analysis.



Plan View of Floor

In-plan flexibility of diaphragm to be considered when $\Delta_2 = 1.5\ \{0.5(\Delta_1 + \Delta_2)\}$

Flexible Diaphragms

A diaphragm may be considered flexible when its midpoint displacement, under lateral load, exceeds twice the average displacement at its ends. They consists of bare metal deck or wood structural panels. Here, relative stiffness of these non-yielding ends supports is very high compared to that of the diaphragm. Therfore, flexible diaphragms are often designed as simple beams between end supports, and distribution of the lateral forces to the vertical resisting elements on a tributary width, rather than relative stiffness. They are not considered to be capable of distributing torsional and rotational forces.

Modelling Perspective

Primary differences Formulation – The infinite in-plane stiffness components of a rigid diaphragm allows the stiffness matrix to condense, decreasing computational time.

- Eccentricity - For rigid diaphragms, the accidental eccentricity associated with seismic loading is concentrated and applied at the center of mass, whereas for semi-rigid diaphragms, accidental eccentricity is applied to every node for seismic loads. If no diaphragm is assigned eccentricity will not be applied to any node. For wind cases and rigid diaphragm, load is applied at geometric centroid, in case of semi-rigid diaphragm loads are distributed in 10 nodes, so that the summation of these forces with respect to centroid will be equivalent to lateral and torsional wind cases.
- Reporting forces - In-plane chord, shear, and collector forces are only reported when using semi-rigid diaphragms.

Flexible floor diaphragms: Here the modelling is done by division of the slab in many sub elements as done in shear walls. This is to say that each shear wall is considered to be a separate structural system.

Rigid floor diaphragms: Here, mass and stiffness characteristics of a structure are combined and a common system characteristic is developed. This arrangement reduces the analysis time drastically.

For normal RC Structure, rigid diaphragm or semi rigid diaphragm can be used. But, the results between these 2 types will be slight different. Semi rigid diaphragm will take much more time to solve the equations since it has so many degree of freedoms. So, it's better to use rigid diaphragm for "NORMAL" RC structure.

However, for transfer beam level. Semi rigid diaphragm should be used or else the transfer beam will have very little axial force only and which is not realistic.

Question 2:

How water-cement ratio and curing affects the durability of reinforced concrete structures? (by Prof. R.J. Shah – Consultant, Ahmedabad)

Answer 2:

In most of the cases, durability of reinforced concrete structures is affected due to corrosion in reinforcing bars provided therein. In normal environment, corrosion in reinforcing bars in reinforced concrete constructions is due to carbonation of cover concrete. In hardened concrete of young age, pH value of pore water is about 13.6 which gives an alkaline environment at the periphery of reinforcing bars. In an alkaline environment, the corrosion in reinforcing bars do not take place. As time passes due to intrusion of moisture and carbon dioxide (CO2 + H20 H2CO3) of the environment in cover concrete, the free lime (Ca(OH)2) generated during the process of hydration of cement reacts with carbolic acid (H2CO3) generating calcium carbonate (CaCo3). Hence, part of free lime (Ca(OH)2) is consumed and pH value of pore water is getting reduced. When pH value is reduced to 9.2 and less, reducing protective alkaline environment which initiates corrosion in reinforcing bars in presence of oxygen and moisture from environment.

The chemical reaction between iron, oxygen and water is highly complex, however to make it simple, through this chemical reactions, which is a process of oxidation, iron turns to iron oxide (rust). Now volume of iron oxide varies from 2.25 to about 6.5 times as compared to volume of iron. Increase in volume of iron due to oxidation gives bursting force to the surrounding concrete and one finds hair crack initially in cover concrete which increases in width due to further oxidation, delamination of cover concrete takes place, and finally cover concrete spalls, exposing corroded reinforcing bars. Due to corrosion, effective area of reinforcing bars is getting reduced, affecting stiffness, strength, performance and durability of reinforced concrete structures.

Permeability of concrete can be reduced substantially by having low water-cement ratio and proper curing of concrete. By providing low water-cement ratio, the thickness of water film around cement particles will be thin and hence, the space between two particles will be less. This can be observed in simplified model of cement paste structure shown in figure 1.

Reference: Properties of Concrete by A. M. Neville

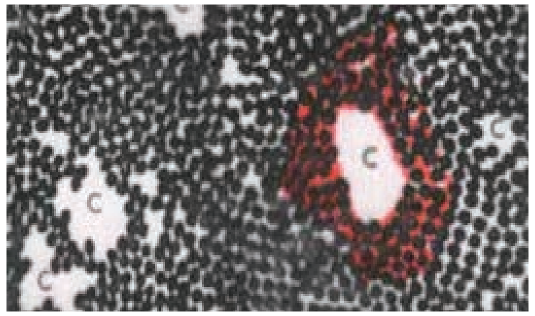
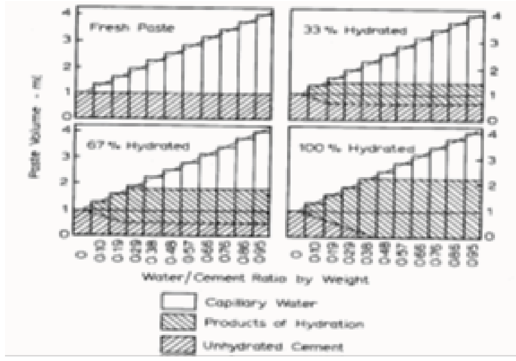


Fig. 1 Simplified Model of Paste Structure

Fig. 2 Composition of cement paste at different stages of hydration



Solid dots represent gel particles; interstitial spaces are gel pores; spaces such as those marked 'C' are capillary pores. Sizes of gel pores is exaggerated. (Red color in part of paste structure indicates the increase in volume of cement particles due to process of hydration, sealing gap between particles)

Through the process of curing dicalcium silicate, tricalcium silicate and tricalcium aluminate are getting hydrated forming silicate hydrates, the volume of which will be about 1.5 to 2.25 times, depending on the degree of hydration of cement. This can be observed in figure 2.

The table given below along with the figure indicates regarding the time and degree of hydration which makes capillaries segmented, which reduces the permeability.

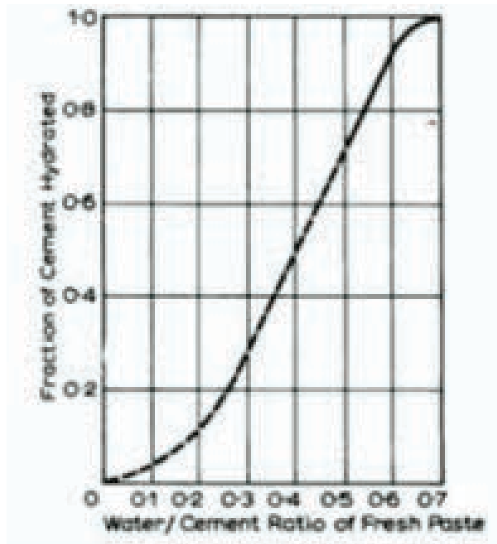
Appropriate Time Required to Produce

Maturity at which Capillaries become Segmented. W/C ratio by weight	Curing time
0.40	3 days
0.45	7 days
0.50	14 days
0.55	3 months
0.60	6 months
0.70	1 year
Over 0.70	impossible

Above stated curing time against various water-cement ratios indicates to achieve segmented capillaries means to achieves lower permeability of concrete, however, to achieve all others properties of concrete, the same shall be cured for 21 to 28 days.

Relation between the water-cement ratio and the degree of hydration at which the capillaries cease to be continuous.

Hence, by providing low water-cement ratio and curing the concrete properly, one can reduce permeability by achieving segmented capillaries which improves the durability of reinforced concrete structures.



Question 3:

What is the impact of using the higher grade of concrete in RCC on overall economy in terms of reduced section sizes and reinforcing steel? By Mr. Rajesh Puri, Mumbai
Reply - Prof. R J Shah, Ahmedabad

Answer 3:

Keeping same grade of concrete and increasing grade of steel, the limiting moment (moment of resistance for balanced section) is decreasing, whereas by increasing grade of concrete and providing same grade of steel, the limiting moment is increasing which can be observed from the table 1 given below:

Table 1 Limiting moment of resistance value, N-mm

The limiting percentage of steel is reducing when we have higher grade of steel with same grade of concrete, whereas when same grade of Steel is used, as you go for higher grade of concrete, the percentage steel is increasing as grade of concrete is increasing, which is observed from table 2 given below:

Table 2 Limiting tensile steel in rectangular sections

Now for a given moment, if both grade of concrete and grade of steel are increased, one will get the advantage. But by doing so the requirement of section may reduce which may have problems with deflection of the same and hence, it should be checked and the depth of section in flexure should be provided accordingly.

Now in high rise buildings and higher spans, high strength concrete and high strength steel can be used appropriately to control the size of section in flexure and compression. Now However Regarding the economy, one will have to work out in detail for a particular building and take appropriate decisions. However for high rise and higher than normal spans, it will be advisable to go for higher concrete strength and high yield steel and the same will turn out to be economical.

Reference: Design Aids for Reinforced Concrete to IS: 456 – 1978.

Table 1 Limiting moment of resistance value, N-mm

Grade of Concrete	Grade of Steel		
	Fe 250	Fe 415	Fe 500
General	0.148 fck b d2	0.138 fck b d2	0.133 fck b d2
M20	2.96 b d2	2.76 b d2	2.66 b d2
M25	3.70 b d2	3.45 b d2	3.33 b d2
M30	4.44 b d2	4.14 b d2	3.99 b d2

Table 2 Limiting tensile steel in rectangular sections

Grade of Concrete	Percentage of Tensile Steel		
	Fe 250	Fe 415	Fe 500
M20	1.76	0.96	0.76
M25	2.20	1.19	0.94
M30	2.64	1.43	1.13

Panel Discussion on “Durability of RCC structure”

- Technical Services Gujarat Team have arranged panel discussion on “Durability of RCC structure” at AKC- Ahmedabad, Baroda and Surat.

- Expert Panelist from Structure and Concrete Field Prof. R J Shah from Ahmedabad, Prof. P V Darji and Er. Pradeep Chauhan from Baroda and Dr. S.N Desai from Surat.
- There were very good questions from participants. Participant have raised their questions and abovementioned expert panelist have clarified these questions / queries at best of their satisfaction.

- Senior professionals from respective locations have attended these panel discussion.
- Regarding suitability of cement from durability point of view, all panelist suggested to use blended cements.
- In future, we have panned panel discussion on different topics.

AKC Events – 75 Technical Event at AKC Cochin

- An endeavor from one of the Largest Cement Producers of India. “Foundations - An Ambuja Knowledge Initiative” is shaped to be one of the most innovative and exhaustive programs for learning about the experiencing cement and concrete like never before for the AEC Community.

- The genesis of the Ambuja Knowledge Centre - AKC is the ambition to create a holistic resource basin on the subject of cement & concrete. It stems from Ambuja Cement’s belief in the continuous evolution of the AEC industries, which enables it to offer its professionals various platforms of information, interaction and inspiration.

- Cochin is one the AKC amongst 27 nos. of AKCs across India. We are arranging various technical lectures, workshops, product showcase etc. in this centre on regular basis for professionals.
- We have Celebrated 75th Technical Event on the subject "Versatility of Concrete". This technical lecture was delivered by Er. Rajen Mankodi on 25-Oct-2016 at Cochin. Sr. Professionals from Cochin and surrounding areas have attended this program.

Highrise Building Design Workshop Highlights

A two days workshop was organised at Mumbai AKC on 20th & 21st Dec'16 on the said topic. It covered on advanced materials required, structural systems, construction techniques, formwork systems etc, Analysis & design of High Rise building by taking a live case, Earthquake & Wind force design was done as per the relevant codes and later by using etab. The faculty comprises of Mr. Prakash Bajaj, Mr, V M Naik & Dr. Nadeem.

Answers of Quiz in ATJ-2

Quiz : Word Search

- Admixture
- Aggregate
- Batching
- Brooming
- Cement
- Concrete
- Durable
- Grading
- Hydration
- Mineral
- Proportion
- Temperature

Cross word

Across

1. Inventor of prestressed concrete - Eugunefreyssinet
2. Inventor of Reinforced concrete - Josephmonier
3. The Indian city in which 1st concrete road was built. - Mumbai

Down

1. An important ingredient for concrete making - Admixture
2. The ingredient which makes up more than 70 % volume in concrete - Aggregate
3. The most consumed construction material - Concrete
4. The country where self compacting concrete was developed - Japan
5. Patented Portland cement - Josephaspidin
6. On his work the self compacting concrete was developed - Okimura.

Quiz 2 Fill in the blank

1. Portland cement was patented in year **1824 ?**

A. 1924
B. 1908
C. 1824

2. The reaction of cement with water is **Exothermic**

A. Exothermic
B. Endothermic
C. None of the above

3. **70 – 75 percent** is the volume occupied by aggregates in Concrete.

A. 20 – 30 per cent
B. 70 – 75 per cent
C. 40 – 45 per cent

4. Segregation in concrete is i) separation of coarse aggregates from mortar, ii) separation of cement paste from aggregates

A. Only i)
B. Only ii)
C. Either i) or ii)

5. Larger the size of aggregate cement paste requirement will be **Lower**

A. Higher
B. Lower
C. Neither of the two

We congratulate all those who have participated wholeheartedly in one or more Quiz Corner, Word Search. We give below the names who have been selected after draw of correct answers.

Names:

1. Mr. Prantika Biswas
2. Mr. Sanjay Mundra
3. Mr. Sankalp Rana
4. Mr. Mitesh Pandya
5. Mr. Ashok Vispute
6. Mr. B.K.Trehan
7. Mr. Laxman Kamble
8. Mr. Pravin Parmar
9. Mr. Mahesh Tandale
10. Mr. Vijay Parmar
11. Mr. Kshitij Shirshat
12. Mr. Gaurav Rastogi
13. Mr. Siddharth Jain
14. Mr. Imran Ahmed
15. Mr. Vikas Gupta

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

Complete the cross word puzzle, word search & quiz, take photograph ans send it across on mail ID: ambuja.technicaljournal@ambujacement.com to be eligible for lucky winner of exiting prizes.

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.

Address of Regional Offices in India – Technical Services

West & South Region	North Region	East Region
Elegant Business Park, MIDC Cross Road "B", JB Nagar, Andheri Kurla Road, Andheri(E) Mumbai - 400059 Tel: 022-40667000	Indicon Viva, 6th Floor, 53 A, Leela Roy Sarani, Kolkata - 700019 Tel.: 033-44033900	228, Udyog Vihar, Phase - 1, Gurgaon - 122016, Haryana Tel.: 0124-4531100

Ambuja foundations

A KNOWLEDGE INITIATIVE