Concrete in India – Need for Rapid Transition


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Workability of concrete is primarily the performance of cementitious inputs in the presence of water. But adding water in the anxiety of getting workability is the bad approach in concrete preparation which has been unabatedly practiced all these years. As a matter of fact, both cement and water are not available totally for workability in normal concrete. Then what happens to the balance? water gets into droplets around which cement particles coagulate due to their electric charge, developing into micro-spheroids, depriving the concrete of their total performance. How to prove it?

When admixture is added during concrete preparation, coagulated cement is getting into matrix as individual particles due to repulsive forces caused by admixture, contributing for enhanced bond so much so additional strength. Simultaneously entrapped water from the coagulated spheroids is released increasing workability for the same water to cement (W/CM) ratio.

Adding fly ash in concrete is not an option but a mandatory need in durability point of view where cost effectiveness is unasked for bonus. Thrust given by 'Advanced Concrete Technology' on packing effect, densification, pore refinement and refined micro-structure; all could be served by fly ash as a single input, rendering 'Sustainable High Performance'.

The rule of game is to identify right quality of fly ash and adding the same in the righteous way by which fly ash performs better than OPC, of course in association with OPC. The proof is pozzolanic activity index (PAI) beyond 1.0 when qualitative fly ash is blended with OPC. Stupendous engineering performance of Nano Concrete is one classic example for this marvelous performance of fly ash. While advocating use of fly ash the authors have broken the convention of concrete preparation through field demonstrations in two ways for the first time in the world:

- Executed 2000 sft of RCC slab in 1991 for the ground floor of FaL-G mansion that contains not even a gram of OPC, having put up 23 years of service life alredy.
- Executed 10.5 ft dia dome (2010) and 1200 sft of RCC slab (2012) with Nano Concrete that contains no sand and stone.

In both the cases fly ash was the principal input, achieving the desired performance better than conventional concrete.

Primitive Practices of Concrete

In erstwhile concept concrete means the combined product of cement-sand-stone that attains rock-like mass through the binding strength rendered by hydrated cement-mineralogy. The old school of thought advocated that strength of concrete is to be attributed to stone, where sand is to fill the gaps among the stones and, role of cement is only to bind the stone-sand matrix. Hence considerable emphasis was laid on strength of coarse aggregate. The importance of cement chemistry was hardly realised in those days limiting the knowledge to its role as binder. There were limited mix proportions randomly in practice in volume ratio such as:

1:4:8 for lean concrete for non-structural application
1:3:6 also for non-structural application
1:2:4 for M15 – for nominal structural application
1:1.5:3 for M20 – for high end structural application
1:1:2 for high very superior structural applications

During course of grinding, cement particles do attain electric charge. Upon added with water, some portion of cement gets coagulated by adherence of cement to water droplets forming as small spheroids. Portion of water entrapped in spheroids do get into hydration chemistry whereas balance of water evaporates, leaving minute hollow spherical pockets in concrete. This means cement of its total input is not available to render the role of binding fine and coarse aggregates together. More over portion of water that got entrapped among cement particles is unavailable for workability, summoning for further water, leading to porosity in the concrete. Hence the challenge has been to achieve desired workability with minimum water and to make the concrete more compact as well as densified. As an approach to achieve these two goals, concrete technologists realised the need of packing that has given credence to the use of graded aggregate.

Graded Aggregates and Mix Design

When there are different sizes of particles in sand and stone, attainment of compaction got improved reducing the voids considerably increasing the density of concrete. This is where the principles of mix design attained significance based on bulk density and specific gravity of inputs together with their particle-size distribution curve towards better densification and strength. Thus prescriptive mix designs became bygone-practice and performing mix designs have emerged as advancement. In the process, specification of zones for sand and adding 10-12 mm as coarse aggregate gained prominence. Designed-mix concretes do attain better workability for same water-cement ratio or, better strengths by reducing water for same workability.

However, in the light of scarcity and erratic supplies of aggregates, construction industry is forced to compromise by accepting them in 'as in where in condition' without choice to insist on specification. Thus field practices go at a tangent to the disciplines of mix design nullifying its sanctity and purpose. This has forced large construction houses and mega projects to set up their own aggregate manufacturing facilities.

In order to enhance the impact of packing effect, vibration is deployed as a means of compaction. Water is added to concrete to attain workability. Since the significance of reducing water during concrete-preparation is realised, low slump concretes are aimed and the hassles of compaction due to low water input is compensated by deploying vibrators. But irrational application of vibration do cause segregation, bringing out the cement paste to the surface, opening chances for plastic shrinkage cracks. Moreover, matrix or concrete is deprived of due cement input. Immense pollution due to inefficient vibrator-engines driven by diesel and/or kerosene is the fallout of this practice.

Raft Foundation with Dynamic concrete (170 kg of OPC/cu.m and strength of 40 MPa)

Concrete with Admixtures

Despite maximizing availability of cement for binding the aggregate, practice of mix design could not avoid formation of micro spheroids so much so porosity of concrete. With the advent of admixtures this issue has been addressed. When admixture is added, it causes repulsion among cement particles, preventing them to adhere to water droplets by which the formation of spheroids is prevented and entrapment of water is avoided. This means cement is totally available for binding activity and water, supposed to be entrapped in spheroids, could be made available for workability.

High Performance Concretes (HPC)

With the advent of superplasticisers, reduction in water and increase in workability have been achieved that made concretes with phenomenal improvement in strengths, proving it plausible to manufacture concrete of M40 and above. To achieve this, coarse aggregate of 20 mm is avoided and 10-12 mm is only used. Higher the grade of concrete more the cement input. With increase in cement-input heat of hydration is increased on one hand and surplus lime in hydrated matrix is increased on the other. While the former tends to cause micro cracks within the concrete-matrix due to thermal stresses, the latter results in leaching out of lime solution causing to develop porosity, diminishing the life of concrete and posing threat to its durability.

Here came the realization about 'sustainable high performance' that in turn emphasized the need for high cementitious content rather than high cement content. This means, OPC has to be reduced but needs to be complemented with commensurate quantity of cement-like materials. In this practice of using multiple inputs, mix designs are prescribed in weight ratios.

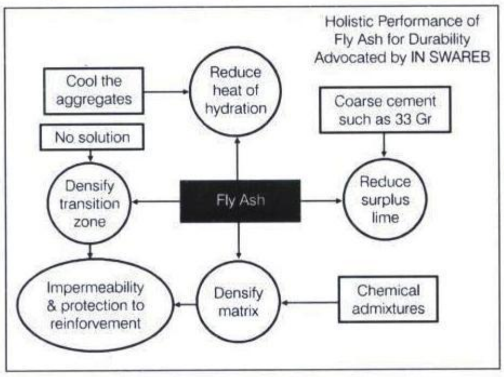
Complementary Cement Materials (CCM)

CCMs are those inputs which have moderate or no heat of hydration but do render hydrated mineralogy akin to that of OPC by availing lime released out of OPC-hydration. Most of the CCMs such as fly ash, ground granulated Blast furnace slag (GGBS), silica fume, rice husk ash (RHA) are industrial byproducts, except metakaoline that is processed out of natural mineral.

By addition of CCM not only lime and heat during OPC-hydration is reduced, but the surplus lime, which otherwise would have leached out, is converted to strength-rendering hydrated mineralogy, contributing for pore refinement and micro-densification of concrete. The result is durability enhancement.

Fly ash and GGBS as popular CCMs:

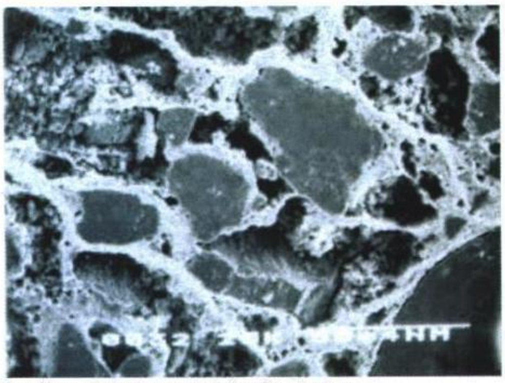
In terms of lime absorption and exothermic heat, relatively class F fly ash is better choice against GGBS. Moreover, fly ash is available with ultrafine particle size of one-μ to facilitate intense chemistry. In other words, while fly ash is added, it performs holistically in reducing heat of hydration, reducing water to binder ratio, development of secondary hydrated mineralogy; all contributing to refinement of transition zone and micro-matrix of concrete as shown in the figure below. In other dimension, fly ash addresses the vagaries resulting out of sacrificing mix design due to rapid changes in aggregate quality at site.



Awareness on Transition Zone in Modern Concrete

In concrete, surplus water laden with dissolved lime tends to settle around coarse aggregate. This zone between coarse aggregate and cement paste is called as transition zone which is the weak zone out of total concrete matrix and, one of the main causes for effecting durability. Higher the size of coarse aggregate greater is the transition (weak) zone. Due to this fact, aggregate size is confined to not more than 12 mm in HPC. The premise of research for Nano

Concrete (NAC) is to avoid the transition zone so much so its weakness in the matrix which has proved phenomenally well for the performance of NAC.



Transition zone showing accumulation of surplus lime

Self Compacting Concrete (SCC)

Further advancements globally over last one decade have given scope for SCC which addresses various issues of concrete preparation and placement in one go:

- SCC facilitates to use fly ash both as CCM and also as micro aggregate.
- Due to use of fly ash, OPC content is lowered to around 200 kg/cu.m rendering minimum strength of M35 that can be enhanced to as high as M80 with marginal increase in OPC input.
- Coarse aggregate size is confined to 12 mm and below.
- Use of admixture is inevitable that, in turn, controls water to binder ratio, making the concrete self-compacting and self-propagating.
- Self-compacted concrete is better than that of vibrated control concrete in microstructure point of view. Hence use of vibrator is redundant, preventing considerable pollution.
- SCC can penetrate to any invisible pocket and most ideal for concreting piles even in hostile soil conditions.

No-Aggregate or Nano Concrete (NAC)

The recent innovation by INSWAREB in the arena of concrete is 'Nano Concrete' that dispenses away the use of both fine and coarse aggregate. The total aggregate is replaced by fly ash which plays the role of micro-aggregate in addition to its performance as 'pozzolan' to the extent of reactive portion. NAC renders more than two times of strength against control concrete with same OPC content, despite reduction in set-density by 25%. With cement content of 340 kg/cu.m strengths have been achieved at 60-80 MPa by 28-day and 95-115 MPa at 1-year. Micro structure studies have shown up best formation of ceramic-like matrix, registering coulomb values at 27 to 300 under rapid chloride permeability test.

During further research on NAC, non-shrinking grout has been developed that is comparable to market grouts on all engineering parameters, just at 40% of cost.

Field demonstrations have been conducted by executing good number of live structures. However, this concrete is being subjected for further structural research before releasing to market for commercial adoption.

Precast roofing panel (5 x 2 mtr) with 50 MPa strength lifted on 7th day

Some mixes developed by INSWAREB for field applications to different clients:				
Constituents/cu.m	**Mix with 12 mm and crushed sand**	**Dynamic Concrete with 12 mm and M. Sand**	**SCC with 12 mm and M. Sand**	**NAC**
OPC	230	170	220	325
Fly ash	300	300	530	1290
Crushed sand	707	-	-	-
M. Sand	-	755	643	-
12 mm	1180	1150	850	-
W/CM	0.31	0.28	0.25	0.15
Mineral admixture-%				20
Admixture - %	1.5	0.5	0.25	0.4
Slump/Flow- mm	210	220	760	Free flow
Strengths: MPa				
1-day	10.0	10.2	9.8	1.50
2-day	22.5	22.5	18.4	25.2
3-day	25.5	27.4	25.2	29.8
7-day	35.5	36.2	32.4	41.5
28-day	52.8	53.9	49.8	62.2

Note: The concrete that functions close to SCC, but lacking its flowability is called as dynamic concrete. Its self-compaction property is almost close to SCC. The rigors of observing W/CM is critical for SCC, whereas dynamic concrete can accept marginal vagaries in W/CM.

Pumping of Dynamic Concrete

Conclusion

The subject of concrete which was merely confined to the mixing and placement of three ingredients viz cement-sand-stone in the presence of water is enlarged to a great dimension through constant research and advanced studies. While strength derived out of cement content was the yardstick to judge the performance of concrete at one point of time, micro structure properties dominate the scene nowadays to decide the soundness of concrete associated with strength derived out of 'cementitious content' instead of mere 'cement' content. Faculty and construction industry need to get exposed to this modern science.

In construction practice, one tends to save cement as economic approach which is reprehensible. But, while saving cement, simultaneous addition of qualified fly ash in commensurate quantity protects the richness of mixes and improves the quality of mortar or concrete with better durability. Scientific rationale and due supervision are essential for resorting to such blends.

World is progressing with high performance structures such as Euro Tunnel (UK-France), Three gorges Dam (China), Petronas Towers (Malaysia), Burj Khalifa (Dubai) etc, but practice of concrete technology at many construction sites in India is still slogging with very primitive approaches. There are good number of engineering consultants in the country who do not accept to avoid river sand and 20 mm in concrete, despite deterioration in their quality. There is an incident of a public sector company, who have successfully practiced fly ash blended concrete for large part of their work, but desisted now from the practice in the apprehension of getting qualified fly ash. While fly ash for Petronas towers was identified abroad and imported in the concern of durability and service life, is it impossible to get qualified fly ash out of 220 million tons of generation in India? While a construction company has conducted series of technical presentations based on sound engineering data and got technical consent for adding fly ash in concrete in irrigation works for durability enhancement, one Chief Minister did pooh-pooh the efforts just based on mysterious considerations!

It does not cost too high to practice advancements in concrete technology but it renders too much of value-addition to the structure with improved life cycle cost. Judicious use of CCM and chemical admixtures would make the concrete more durable, cost effective and sustainable with long life; all serving the need of the millennium ie., green technology with least carbon foot print accomplishing the agenda of Sustainable Development. ♦