High Performance Concrete in Aggressive Environments

Satish Kumar Sharma[#], Sudesh Kumar Sohani[#]
[#]*Professor, Department of Civil Engineering, Acropolis Institute of Technology and Research, Indore, India*

***Abstract*— There is need and necessity of proper choice of materials to fulfill the requirements of proper workability, strength and durability. The paper focuses on the latest trends in this direction and presents critical analysis with particular reference to high performance concrete. The paper incorporates national and international experiences on the subject. There is specific discussion on roller compacted concrete, high volume fly ash, micro-silica and special cements particularly against aggressive environments.**

***Keywords*— Roller compacted concrete, High volume fly ash, micro-silica, aggressive environments, Self compacting concrete, High performance concrete.**

I. INTRODUCTION

High performance concrete exhibits not only a desired grade of concrete but also other parameters which could be in respect of particular level of workability, modulus of elasticity or any other engineering characteristics. The paper reviews the current situation in respect of roller compacted concrete and concretes involving replacement of cement by flyash upto about 60%. Of late, microsilica found use in a number of flyovers and other projects. There is discussion regarding the choice of special cements in aggressive environments of chlorides, sulphates etc.

A. High Performance Concrete (HPC)

HPC [1],[4] contains materials like flyash, silica fume (micro-silica) and granulated blast furnace slag and also a super plasticizer. Ingredients and proportions in HPC are so chosen as to have appropriate desired properties during the life of the structure. These properties could be high strength or a low permeability or other engineering characteristics. Thus, HPC is a broad term in the perview of which, high strength is just one of the parameters and incorporates other engineering characteristics like durability and particular level of workability while making and placing concrete.

Self Compacting Concrete with very high workability as well as high compressive and flexural strength has been used in a number of projects like Delhi Metro and is already in use in various parts of the country.

B. Roller Compacted Concrete [2],[3]

It is a recent development in the field of construction of rigid pavements and dams. It is a lean, 'zero' slump concrete and is compacted by a vibratory roller. High volume fly ash to the extent of 60% by weight of cement have been reported in India and abroad. The cement content ranges from 60 to 360 kg per cubic meter.

Roller compacted concrete is placed in thin layers of 20 to 30 cm. Compressive strength of 7 to 30 MPa have been obtained. The concrete must be dry enough to support the mass of the vibrating equipment. A dam using roller compacted concrete was completed in Japan in 1980 and subsequently ninety six dams were constructed in 17 different countries in the next 7 years, mainly in USA, Spain and Japan etc.

Roller compacted concrete was used in the construction of Delhi- Mathura road and Pune - Mumbai highway construction. M 10 concrete with base course 15 cm thick was used. Pavement quality concrete of grade M 40, 35 cm thick was laid over this base course.

C. Supplementary Cementing Materials (SCM) in concrete [3],[4],[5]

Micro-silica (or Silica fume) is a by-product resulting from reduction of high quality quartz with coal in an electric arc furnace in the manufacture of silicon or ferro-silicon alloy. It is used as a mineral admixture and when used with super plasticizer results in high early strength in concrete. Silica fume has pozzolanic action. For compressive strength of 100 MPa and above, the use of silica fume is essential. It was used in 2 flyovers in Mumbai. In India, there is practical difficulty in availability of silica fume of good quality and the material available does not compare well with silica fume being imported from USA.

While micro-silica is instrumental in generating high early strength, fly ash contributes to compressive strength of concrete at later ages. Concrete containing upto 60 % flyash has been used in India and abroad and exhibited excellent strength and durability characteristics. High volume fly ash has been used in multi-storied structures, water front structures, concrete roads and roller compacted concrete in dams. It resulted in economical works.

D. Concrete against aggressive environments

After conducting extensive laboratory and field studies [6] at IIT Madras and various sites, it was concluded that fly ash admixed concretes performed the best in aggressive environments. OPC and Sulphate resisting cement admixed with flyash were named as OPF and SRF respectively. Replacement of cements by fly ash was done as per formula evolved by Central Building Research Institute, Roorkee and is given hereunder:

i. Replace 20% of cement by 27.5% of fly ash by weight.

ii. Reduce quantity of fine aggregate to the extent of weight of added fly ash.

iii. Increase quantity of coarse aggregates to the extent of

weight of added fly ash.

iv. Reduce water content by 8% as compared to that in normal cement concrete without fly ash.

The formula as above exhibited compressive strength of fly ash admixed concrete equivalent to cement concrete without fly ash at 28 days.

Based on the detailed studies in labs. of IIT Madras and field studies in a chemical plant and marine environment at Chennai and Mandapam, the following choices of cement concrete are recommended:

TABLE I

Choice of Special Cements in Aggressive Environments.

Environments	Cements		
	Normal Cement	Blended Cement	Cement with Fly ash replacement
Chlorides	OPC(admixed with water proofing admixture)	Portland Blast Furnace Slag Cement	OPF
Sulphates	Sulphate Resisting Cement	Portland Blast Furnace Slag Cement	SRF
Chlorides + Sulphates	Sulphate Resisting Cement	Portland Blast Furnace Slag Cement	SRF
Nitrates	Sulphate Resisting Cement	Portland Blast Furnace Slag Cement	SRF

It was established that SRF performed very well against sulphates while OPF performed very well against other aggressive environments of chlorides nitrates, sea water etc. in general.

Performance of PPC and Portland Blast Furnace Slag Cement was also seen to be better than that of OPC in aggressive environments in general.

It is brought out that proper quality control in concreting with the minimum required water/ cement ratio is of prime importance. Choice of cements as above cannot be substitute for good engineering practise.

II. CONCLUSIONS

With advancements in concrete technology, it is seen that in times to come, more and more use of micro- silica and high volume fly ash will be seen in various projects. Roller compacted concrete is already in use in rigid pavements and dam construction. Self compacting concrete has been extensively used in Metro- rail projects in India. Fly ash admixed concretes, OPF and SRF were seen to be particularly effective against aggressive environments from the standpoint of durability, workability and strength. With advancements in concrete constructions, more and more structures and other civil works would come up in India in times to come.

ACKNOWLEDGMENT

Authors are grateful to Prof. Nupoor Kumbhkar for setting right the paper in the required format.

REFERENCES

[1]. Neville, A. M. (2013). Properties of Concrete, Pearson Education Limited, 5th edition, pp.651.
[2]. Seehra, S. S.(1997). Roller Compacted Concrete- A New Construction Technique for Rigid Pavement and Quality Construction, Indian Roads Congress, International Seminar on New Trends in Highway Constructions, New Delhi, pp. I-31-38.
[3]. Shetty, M.S. (2012). Concrete Technology, S. Chand and Co. Ltd., New Delhi, pp.570-571.
[4]. Goodspeed, C. et.al.(1996). Indian Concrete Institute. High Performance Concrete, SHRP HPC Showcase, New Delhi(USA and India Seminar), pp.1-14.
[5]. Lewis, R.E. (2001). Improved Performance and Durability through the Combined Effects of Fly Ash amd Micro-Silica, ACI, India Seminar, Mumbai, pp.111-120.
[6]. Sharma, S. K. (1993). Performance of Concrete and Reinforced Concrete Materials in Aggressive Environments, Ph.D thesis, IIT Madras, Chennai