
DISCUSSION FORUM

Delhi Metro: Quality control of concrete for underground section

I wish to compliment the learned authors on the paper titled "Delhi Metro : Quality control of concrete for underground section", published in the April 2005 issue of the *Journal*¹. They have been frank in admitting defects, which arose during execution and measures taken to remedy. In this regard, I have some specific comments for clarification.

- (i) Was any attempt made to transport the cement in bulk to the site of ready-mixed plants to ensure exact quantity usage of cement without suffering any loss in normal bags supply that is usually experienced.
 - (ii) For the purpose of durability, cement for construction should be selected on the basis of its pH potential which is a determinant along with pore water. What was the criterion adopted while selecting cement? Was any protection with a waterproofing system applied on the underground exposed face of concrete structures/tunnels?
 - (iii) The structures have been reported to be designed for a life of 120 years. Both ground surface and ground water in habited areas is bound to get contaminated and the effect of such contamination needs to be taken into consideration while predicting long life. Analysis of the soil and ground water in most of the metropolitan towns indicate high level of toxicity. Mere use of chloride-free cement initially is not going to ensure long service life.
 - (iv) The specifications for large-scale use of SCC adopted for such work would be of interest to professionals and may be indicated in full.
 - (v) The use of fly ash in concrete construction for long-term durable performance as also guarantee on absence of radioactive behaviour should be specifically commented.
- (vi) Was any instrumentation introduced for monitoring in-service behaviour of the structures and schedule of directed inspection laid? The result of NDT tests done with specific mention of accuracy attained may be commented upon.

Mr A K Bhattacharya
H-2A, Hauz Khas
New Delhi

The author's reply

On behalf of my co-authors, I wish to thank the discussor for going through our paper with so much interest and for his keen observations. My point-by-point reply is given below.

- (i) Cement was not obtained by RMC in bulk. Every grade of concrete contains the exact quantity of cement as per the mixture proportioning.
- (ii) Cement was selected on the basis of its physical and chemical properties. Further, what is important from durability considerations is the pH and the total chlorides in concrete (not just in cement) and the impermeability of concrete. The low values of water permeability (*Table 6* of the paper) indicated good durability.
The external surface of the segments which showed minor cracks less than 0.2 mm in width were provided with waterproof coating.
- (iii) Geological survey was carried out by employing expert agencies along with longitudinal section of the railway line. Considering the quality of ground water that existed at the start of the project and extrapolating on future contamination, the design of concrete was based on the designer's experience elsewhere in the world.
- (iv) Delhi Metro has used maximum amount of SCC (10,000 m³ at about

40 locations) which is higher than that used in any construction in India during the year 2004. Details of SCC used in the Indian context, are given elsewhere².

- (v) Initially, the specification did not include the use of fly ash. Fly ash was not included probably due to the lack of awareness of foreign consultants regarding the availability of good fly ash around Delhi. On identifying the good quality fly ash at Dadri, the same was incorporated in the mix after testing and specifying about its physical and chemical properties as per latest specifications of the Bureau of Indian Standards. BIS specification does not include the test for radioactive behaviour. The authors did not wish to go into such great detail on material science properties. Perhaps, a separate paper may be written for such details.
- (vi) No instrumentations have been introduced for monitoring the in-service behaviour of the structures. The results of the NDT tests carried out are not really extra ordinary in this project. It has been mentioned in the paper that combinations of NDT tests showed that the quality of concrete can be grouped in "excellent" category as per IS code.

Prof M.S. Shetty
No. 4, Sopan Baug,
Pune 411 001

References

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2. VACHANI, S.R. CHAUDHARY, RAJIV and JHA, S.M.
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