Reliability of accelerated curing techniques for speedy design of concrete mixes – An appraisal of IS 9013:1978 code

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In spite of all its advantages, the time factor is one major cause for the construction engineers to go for proper mix designs. In Indian conditions, it is often not possible to get materials from the same source throughout the construction stage. Each time when the materials (especially cement) changes, spending 45-60 days for a fresh design is often impractical. This demands a lookout for other options. The method developed by the national council for building materials [1] based on accelerated curing of concrete (IS 9013:1978, reaffirmed in 2004) is apparently an exciting solution to this problem as it can produce the results in two to three days. An inquest is made here on the reliability of this method on practical problems.

INTRODUCTION

It is established that a statistically significant correlation exists between its 28-days strength and accelerated strength [2]. Tests conducted on different grades of concrete, and using different brands of cements from different parts of the country have proved that this correlation is not affected by variations in grades of concrete and types of cement [2]. As per the new guidelines for the design of concrete mixes [3], the designer is fixing the W/C for the first trial based on Table 5 of IS 456:2000 [4] and his personal experience and not based on the cube strength of cement cubes. Accordingly in accelerated design also, the step of finding the strength of the reference cube gets eliminated and that makes the procedure further simple.

Hence, the mix design procedure is exactly the same as described in IS 10262:2009 for normal design of concrete mixes and the only difference is that the 28-days can be determined on the next day (as described below by accelerated test procedure) of casting of cubes and then it can be compared with the required target strengths.

Accelerated test procedure [2]: After the specimens are cast (150 mm cubes), they should be kept in a humid environment (90% humidity and 27+2°C temperature for 23 hours + 15 minutes (time should be counted from the time of addition of water to the ingredients). The specimens shall then be gently lowered into the curing tank containing boiling water and shall be kept in that condition for 3 ½ hours + 5 minutes. Then the specimens shall be removed from the boiling water, removed from the mould and cooled by immersing in water (27+2°C temperature)

for 2 hours. The specimens shall then be tested for compressive strength. The age of the cubes at the time of testing shall be 28 ½ hours + 20 minutes.

THE STUDY CONDUCTED

Test were conducted at the accelerated curing tank at the Construction Materials Division of the Kerala Engineering Research Institute. Though initial studies were not very encouraging added to minor shortcomings in precisely following the procedure due to lack of experience, initial results themselves were indicating that the formula used, may require some modification. It was therefore necessary to generate adequate test data. To get sufficient data, accelerated strength determination was conducted on all mix designs for various grades of concrete from M25 to M40. Accelerated testing was conducted with extreme care to ensure that described procedure is followed throughly. The results of the same were compared with the 7 and 28 days strengths of the normally cured cubes. In all 9 cubes of same water cement ratio were cast and the averge of the 3 cubes wre considered for 7 days, 28 days and for accelereated curing method.

CASE STUDY-1

Materials used

Cement: OPC 53 grade cement conforming to IS 12269, Brand: A regional brand

Fine aggregate: Quarry sand conforming to Zone-1 of IS 383, Specific gravity 2.65

Aggregates: Crushed granite cubical aggregates 20 mm and down 70% and 12.5 mm and down 30%. Specific gravity-2.75

Admixture: A commerical brand @ 300ml per bag of cement.

Workability: A slump of over 150 mm (for pumping)

Table 1. Comparison of the 28 days strength arrived at by the accelerated test procedure with those achieved by normal procedure

Mix proportion (per cubic meter of concrete)	Approx W/C	Average (of 3 cubes) 7 days strength (N/mm^2)	Average (of 3 cubes) 28 days strength (N/mm^2)	Average (of 3 cubes) 28 days strength determined by accelerated curing method (N/mm^2)	
				R_a	$R_{28} = 1.64*R_a + 8.09$
Cement-400 kg, FA- 802.571 kg, CA- 1017.94 kg, Water-197.60 lit, Admixture- 2.40 lit.	0.50	21.56	**35.41**	10.89	**25.95**
Cement-408.16 kg, FA- 799.481 kg, CA- 1014.02 kg, Water-197.551 lit, Admixture- 2.449 lit.	0.49	27.26	**41.19**	15.11	**32.87**
Cement-416.667 kg, FA- 787.415 kg, CA- 1019.12 kg, Water-197.5 lit, Admixture- 2.5 lit.	0.48	33.63	**45.33**	14.89	**32.51**
Cement-434.783 kg, FA- 771.861 kg, CA- 1019.44 kg, Water-197.391 lit, Admixture- 2.609 lit.	0.46	35.41	**51.41**	22.52	**45.02**
Cement-454.545 kg, FA- 755.858 kg, CA- 1018.79 kg, Water-197.273 lit, Admixture- 2.727 lit.	0.44	36.59	**53.33**	16.89	**35.79**
Cement-476.19 kg, FA- 739.34 kg, CA- 1017.04 kg, Water-197.143 lit, Admixture- 2.857 lit.	0.42	39.70	**56.15**	21.63	**43.56**

A huge difference between the actual 28 days strength and the projected strength based on accelerated test was noted as seen from Table 1. Care was taken to use exactly the same materials for all the six designs. It can be seen that the projected strength obtained for water cement ratio of 0.46 was more than that with water cement ratio of 0.44 and 0.42. The actual 28-days strength for this water cement ratio is also slightly higher than what was expected. More tests were conducted to develop a fresh correleation equation betwen these strengths. The results are furnished below:

CASE STUDY-2

Materials used

Cement: OPC 53 grade cement conforming to IS 12269, Brand: A regional brand
Fine aggregate: Quarry sand conforming to Zone-2 of IS 383, Specific gravity 2.67
Aggregates: Crushed granite aggregates 20 mm and down, Specific gravity- 2.75
Admixture: Nil
Workability: A slump of 50 mm to 100 mm (medium)

CASE STUDY-3

Materials used

Cement: PPC conforming to IS 1489- Part-1,
Brand: A regional brand.
Fine aggregate: Quarry sand conforming to Zone-2 of IS 383, Specific gravity 2.65
Aggregates: Crushed granite aggregates 20 mm and down, Specific gravity- 2.79
Admixture: Nil
Workability: A slump of 50 mm to 100 mm (medium)

These subsequent results are also found not very encouraging. Only the last result (table 3) appears to be somewhat in agreement.

Table 2. Comparison between actual strength and projected strength

Mix proportion (per cubic meter of concrete)	W/C	Average (of 3 cubes) 7 days strength (N/mm^2)	Average (of 3 cubes) 28 days strength (N/mm^2)	Average (of 3 cubes) 28 days strength determined by accelerated curing method (N/mm^2)	
				R_a	R_{28}=1.64*Ra+8.09
Cement-400 kg, FA- 682.842 kg, CA- 1147.49 kg, Water-200 lit.	0.50	22.00	**35.63**	9.63	**23.89**
Cement-408.16 3kg, FA- 676.632 kg, CA- 1146.76 kg, Water-200 lit,	0.49	22.59	**38.52**	9.41	**23.52**

Table 3. Another comparison between actual strength to projected strength

Mix proportion (per cubic meter of concrete)	W/C	Average (of 3 cubes) 7 days strength (N/mm^2)	Average (of 3 cubes) 28 days strength (N/mm^2)	Average (of 3 cubes) 28 days strength determined by accelerated curing method (N/mm^2)	
				R_a	R_{28}=1.64*R_a+8.09
Cement-448.98 kg, FA- 628.87 kg, CA- 1089.48 kg, Water-220 lit.	0.49	20.67	**29.34**	11.93	**27.66**

SCRUTINY OF THE CORRELATION EQUATION

The equation correlating the accelerated strength and the 28 days strength is basically a linear fit.

$R_{28} = 1.64*R_a+8.09$

When R_a gets close to Zero, one gets a fairly good R_{28} of 8.09 N/mm^2 which does not make much sense. Similarly for higher values of R_a, a question may arise whether an increase of 1.64 times is good enough. Even a preliminary analysis would hint that to get a realistic estimate of R_{28}; the constant, the Y-intercept has to be reduced considerably from 8.09, may be even to Zero. The slope of the line should be increased from 1.64 to a value probably between 2.5 and 3. Thinking about developing a quadratic equation of correlation is desirable.

CONCLUSION

The studies conducted has given totally discouraging results for the reliability of accelerated curing techniques proposed by the Bureau of Indian Standards. To develop and suggest a new correlation equation, much extensive studies and data analysis are required. But to establish that the current method is not dependable, these studies are ample. It is an extremely involved effort to do the accelerated strength tests according to the code specifications. But then if the results are inconsistent it is very disappointing. It is suggested that BIS may seriously look into the issue of revising the concerned code by referring to the international codes which are more elaborate in this subject.

References

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2. _____*Method of making, curing and determining the compressive strength of accelerated-cured concrete test specimens*, IS 9013:1978 (reaffirmed in 2004), Bureau of Indian Standards, New Delhi.
3. _____ *Concrete Mix proportioning - Guidelines*, IS 10262:2009, Bureau of Indian Standards, New Delhi.
4. _____*Plain and reinforced concrete - Code of practice*, IS 456:2000, Bureau of Indian Standards, New Delhi.

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