Discussion Forum

Mix proportioning of plain and rice husk ash concrete as per draft IS 10262

This has reference to the paper titled 'Mix proportioning of plain and rice husk ash concrete as per draft IS 10262' by M.C. Nataraja and B.M. Ramalinga Reddy published in the March 2007 issue of, 'The Indian Concrete Journal'.

The authors have presented an important paper on proportioning of concretes using the draft IS code. The paper is well written and brings out clearly various aspects of concrete mix design. It is made very clear that the actual mix design involves the experimental work with the given ingredients and the computations are meant only for starting the trial mixes in the laboratory. With a view to supplement the points described in the paper, the following views are offered for careful consideration by the authors and engineers:

The authors are to be thanked for describing completely the ingredients of the concretes by listing the numerical values for the important characteristics. The loss of ignition (LOI) of mineral admixtures is usually expressed as percent loss by mass. The authors have given the LOI of rice husk ash (RHA) as 1.5 g/cc and the authors may explain, for the benefit of readers, how this is computed and what would be the value in percentage terms ?

The minimum compressive strength of the 53 grade OPC as per IS 12269 has to be 53 MPa and not 43 MPa as mentioned in Table 1 under the column heading 'IS 12269 : 1987 requirements'. However, the actual cement used in the study can be classified as 53 grade as mentioned correctly by the authors under the para 'Cement', since the 28 day strength of cement is 56.47 MPa which is more than the threshold value of 53 MPa.

The authors have used the draft IS 10262 for mix design calculations. The writers have noticed from the authors' computations under the paragraph 'Mix calculation by absolute volume method' that this draft code does not require the information on air content of concrete to be used in the calculations and this aspect is always considered in the mix design guidelines given by many prominent institutions such ACI[1,2]. The air content of concrete is though a small value and is an estimation of the value given depending upon the maximum size of coarse aggregate. The writers feel that a guideline to include the air content of concrete in the design calculations should be included in the final version of the code. The authors may provide their valued views on this for the benefit of practical mix designers.

The authors have given the computations for the contents of 15% RHA concrete mix and mentions them as Cement : FA : CA = 372 : 630 : 1128 kg/m^3 . The writers feel that the term 'Binder' instead of 'Cement' would have been more appropriate here since the quantity of 372 kg/m^3 mentioned consists of cement of 316.2 kg/m^3 and RHA of 55.8 kg/m^3. Regarding the water content of concrete for computation of water-cement ratio or water-binder ratio, the engineers have to note that the actual water content in SP is also to be accounted. However, for minor content of SP in concrete, the contribution to water content from SP may not be significant, as in the present case.

The authors mention the contents of final M30 grade OPC concrete mix in Table 5 and it would be useful to the readers if this information regarding the final RHA concrete mixes is also given. The authors can also inform the changes in fresh concrete density observed due to presence of RHA (as cement replacement material) which has specific gravity much less than that of OPC.

The authors have presented very clearly practical ways of changing the proportions based on the inspection of test results of already cast specimens to meet the desired requirements of strength and workability in concretes. They have also rightly recognised, under the para 'Conclusion', the need for reducing the number of trials using rational approaches such as Abram's law. In this regard, the writers wish to suggest the use of following two concepts viz. cementing efficiency of RHA and Bolomey Equation for compressive strength of concrete for consideration by the authors and readers, especially for design of concretes with mineral admixture (MA) such as RHA:

(a) Cementing efficiency factor, 'k':

This describes the mineral admixture's ability to act as cementing material recognising that MA's contribution to concrete strength comes mainly from its ability to react with free calcium hydroxide produced during cement hydration[3,4,5]. The rate of this reaction, called as pozzolanic reaction (PR), when compared to cement hydration rate (CHR) determines the value of 'k'.

When k=1, both PR and CHR would be same and the water-binder ratios of concretes with and without MA could be almost same.

When k<1, PR would be slower than CHR and for equal strengths, the water-binder ratio of concrete with MA need to be less than that of concrete without MA. And also, at same water-binder ratio, the strength of concrete with MA would be less than that of concrete without MA. In this case, the MA is less efficient than Portland cement in imparting strength to concrete. The fly ash has generally k<1 at early ages and 'k' would reach a value of unity at later ages.

When k>1, PR would be faster than CHR and for equal strengths, the water-binder ratio of concrete with MA would to be more than that of concrete without MA. However, at similar water-binder ratios, the strength of concrete with MA would be more than that of concrete without MA. In this case, the MA is more efficient than Portland cement in imparting strength to concrete. Silica fume has generally k>1 even at early ages and therefore, the strengths of silica fume concretes are more than that of cement concretes at similar water-binder ratios.

In the present case of RHA, the authors' test data shows that the strengths of cement concretes (CCs) are generally less than that of RHA concretes (RHACs) and therefore 'k' of RHA <1. However, it is seen that at equal water-binder ratios, the difference between CC and RHACs reduce with age indicating that 'k' of RHA increases with age.

(b) Bolomey Equation for concrete:

This is written as[6]:

$$S = A\,[(c/w)\,] + B \qquad ......(1)$$

where, S = compressive strength, C = cement content, W = water content, A and B are constants for given ingredients of concrete.

Equation (3) has been shown to practically reduce to following two equations[7]:

$$S = A[(C/W) - 0.5] \qquad ......(2)$$

$$S = A[(C/W) + 0.5] \qquad ......(3)$$

These two equations represent two ranges of concrete strengths and it is due to the often observed fact that a change in slope occurs at about w/c = 0.40, when C/W (cement-water ratio) is plotted against strength. However, the writers have found that the equation (2) is useful for most of the present day concretes when an analysis was done on test results available at SERC and also the extensive data published by Hansen[8]. Larrard also mentions this equation in his famous book, on 'Concrete Mix Proportioning – A scientific approach[9]. Therefore, equation (2) can be generally used for re-proportioning. The value of constant 'A' can be found out for the given concrete ingredients, by considering a concrete mix of any w/c ratio. This equation can be modified for concretes containing MAs using the factor 'k' :

$$S = A[(1 - p + p\times k)/(W/B)) - 0.5] \qquad ......(4a)$$

$$S = A[(1 - p + p\times k)/(wb) - 0.5] \qquad ......(4b)$$

where, p = Fraction of MA in the binder, B = Binder content = C + F, F = MA content = p×B, C = Cement content = (1-p)×B, W= Water content, W/B = wb = water-binder ratio.

We may note that in concrete without MA, p = 0, F = 0, B = C, wb = wc, where wc is the water-cement ratio. The value of 'A' can be obtained from the test results of cement concretes without MA and the same is used for concretes with MA in equation (4).

To successfully use the equation (4), we have to get an idea of 'k' for the MA. The 'k' value for the given MA, say RHA in the present case can be obtained from the test results using above equations. However, for the purpose of discussion, the value 'k' for RHA is assumed to be 0.4 and it is increased to 0.7 at 28 days. At 56 days, 'k' is taken to be nearly unity, say about 0.95, since the strengths of both CCs and RHACs are nearly same.

Table A. Computations for Bolomey equation for RHA concretes at wb = 0.50

Age, days	RHA, %	'k'	wb	S_{test}, MPa	'A'	S_{eqn}, MPa	Diff, %
7	0			36.2	24.1		
	15	0.4	0.5	33.7		31.9	-5.5
	25	0.4	0.5	27.6		29.0	4.9
28	0		0.5	43.0	28.7		
	15	0.7	0.5	40.0		40.4	1.1
	25	0.7	0.5	35.5		38.7	9.0
56	0		0.5	43.5	29.0		
	15	0.95	0.5	43.1		43.1	-0.1
	25	0.95	0.5	42.4		42.8	0.9

% Diff = 100 × (S_{eqn} - S_{test}) / S_{test}, wb = Water-binder ratio

With references to the mixes given in Table 4 of the paper, the equation (4) is applied to obtain Table A (page 46):

In Table A, the value of 'A' is obtained at each age from the test results on CCs and the same was used for RHACs to compute S_{eqn}. The difference between predicted value, S_{eqn}, and test value, S_{test} is in the range of –5.5% to 9.0% which can be accepted as negligible from practical considerations. Table B was prepared for final mixes of the authors.

In Table B, the value of 'A' is obtained at each age from the test results on CC and the same was for RHACs to compute S_{eqn}. The difference between predicted value, S_{eqn}, and test vale, S_{test} is in the range of –0.6% to –7.6% which can be accepted as negligible from practical considerations.

Tables A and B show that the equation (4) can be used for design and re-proportioning of RHA mixes. However, there is a need to estimate a reasonable value of 'k' which can be based on previous experience or obtained from specifically conducted tests on concretes with and without RHA.

The authors have presented very explicitly under paragraph 'Selection of water-cementitious ……' that the relationship between free w/c ratio and concrete strength are necessary for mix design and in the present case, the w/c ratio was based on trial mixes. However, the writers suggest the use of following equation[10] (similar to Eqn 2 given above) which is based on the mix design curves A to F in BIS publication SP23 (S&T)[11]:

$$S = 0.39 \times f_{cem} \times [1/(wc) - 0.5] \qquad ......(5)$$

where, f_{cem} = Cement strength determined as per IS 4031. Recently, the writers found that the factor 0.39 in above equation (5) seems to be not valid for present day cements and a higher factor is often applicable. Therefore, the following equation is suggested.

$$S = 0.45 \times f_{cem} \times [1/(wc) - 0.5] \qquad ......(6)$$

Table B. Computations for Bolomey equation for finalised concrete mixes

Age, days	RHA, %	'k'	wb	S_{test}, MPa	'A'	S_{eqn}, MPa	Diff, %
28	0		0.50	39.3	26.2		
	15	0.7	0.50	40.0		37.0	-7.6
	25	0.7	0.48	37.6		37.4	-0.6

% Diff = 100 × (S_{eqn} - S_{test}) / S_{test}

Applying this to the authors' cement strength (at 28 day) of 56.5 MPa, the concrete strength for wc ratio of 0.50 works out to 38.3 MPa which is almost similar to 39.3 MPa reported by the authors in Table 5. Thus, for preliminary trials, the above equation can be utilised when an idea about the actual cement strength (not only the grade of cement) is available. This would remove arbitrariness of selection of wc ratio of concrete for given concrete strength (and concrete grade).

Mr N.P. Rajamane
Deputy Director
Concrete Composites Lab,
Structural Engineering Research Centre
CSIR Campus, Taramani, Chennai 600 113

References

1. ______*Recommended Practice for Selecting Proportions for Normal, Heavy Weight, and Mass Concrete*, ACI Committee 211.1, ACI Manual of Concrete Practice, 2006.
2. *Guidelines for Selecting Proportions for High Strength Concrete with Portland Cement and Fly ash*, ACI Committee 211.4, ACI Manual of Concrete Practice, 2006.
3. Ganesh Babu K., and Sivanageswara Rao, G.S., Effect of fly ash in concrete. *Cement and Concrete Composites*, 1993, Vol. 15, pp. 223-229
4. Smith, I.A., Design of fly ash concrete. *Proceedings of Institution of Civil Engineers, London*, 1967, Vol. 36, pp. 769-791
5. Joshi, R.C. and Lohtia, R.P., *Fly ash in concrete : Production, properties and uses*, Gordon and Breach Science Publishers, Netherlands 1997.
6. Bolomey. J., Granulation et prevision de la resistance probable des betons, *Travaux*, 1935, Vol. 19, No. 30, pp. 228-232.
7. Brandt, A.M. Ed., *Optimisation methods for material design of cement-based composites*, 1995, E & F N Spon.
8. Hansen T.C. and Hedegaard S.E., Modified rule of constant water content for constant consistency of fresh fly ash concrete mixes, Materials and Structures, 1992, Vol. 25, No. 150, pp. 342 – 354.
9. de Larrard F., *Concrete Mixture Proportioning : A Scientific Approach*, E and F N Spon, 1999.
10. Rajamane, N.P., A general formula to replace concrete BIS mix design curves of SP:23 (S&T)-1981, *New Building Materials and Construction World*, Vol. 10, No. 11, May 2005, pp 124-129
11. ______*Handbook on concrete mixes*, SP 23 : 1982, Bureau of Indian Standards, New Delhi, pp. 122.

Continued on page 55

The authors' reply

The authors thank the discusser for the keen interest in our paper. It is good that the discusser who is known for his active research in the area of concrete has appreciated the work. The authors would like to clarify the points raised by the discusser. The explanations are in the order of his comments. The authors thank the discusser for his views to supplement the work.

The RHA used in the present work is tested at CPRI, Bangalore and the results as furnished by the institute are reported in the paper. As per the clarification from CPRI, the LOI is to be expressed as percentage. The LOI of 1.5 g/cc is wrongly reported and it is to be read as 1.5 %. Thanks to the discusser for identifying the typographical mistake.

In Table 2, the 28 day compressive strength of 53 grade cement as per IS 12269 1987 be read as 53 MPa instead of 43 MPa[1]. Authors thank the discusser for this correction.

The draft code does not allow the use of air content in the mix design. This is one of the major changes made in the draft code on mix design. However, in the existing IS 10262 : 1982 code air content is allowed which depends mainly on the maximum size of the aggregate and the same has been pointed out by the discusser.[2] The air content mainly depends on the mix proportions and in practice the nominal maximum size of the aggregate is used as a parameter[3]. The amount of entrapped air can be as high as about 3% for 10 mm nominal maximum size of aggregate for non-air entrained concrete. For 150 mm size of aggregate it can be as low as 0.2%. In case of air entrained concrete, the air content is still higher and depends on the amount of workability required and the type of exposure in addition to the nominal maximum size of the aggregate[3,4]. It is very well documented in ACI 211.1-1991[5]. As the future concrete is more of high performance type involving different types of admixtures, there is enough scope for certain amount of air to be entrapped. Authors can not find any reason for omission of the air content in the draft code and strongly feel that this needs to be included as it is useful in the calculation of density of compacted concrete and its yield[3]. Authors also supplement the suggestions of the discusser and feel that the air content may be allowed in the final version of the code similar to that available in the existing IS 10262 : 1982 and other international codes on mix design[2]. This may need further discussion with concrete technologists working in this area.

In the paper cement means cementitious materials. When no supplementary materials are used, then it is 100% OPC. In the case of replacement, cement represents both OPC and the supplementary material. The term binder is the right term as suggested by the discusser. Authors rightly agree that the water content of SP should also be considered in w/c calculation. As it is a very small quantity, it has been neglected and the same is reported for clarity. If the water of the SP is considered then it is fluid-binder ratio instead of w/c ratio. Authors thank the discusser for his suggestions.

It is true that the density of RHA concrete will be less than that of plain cement concrete as the specific gravity of RHA is less compared to that of cement. In case of 15% replacement of RHA, a marginal decrease in the density of hardened concrete has been observed. However, in case of 25% replacement, the reduction in density is about 10%. This is based on the weight of the cubes and its dimensions on the day of testing. Fresh concrete density was not found in this work.

The first author has reported the importance of rational approaches in the concrete mix design for reducing the trials. The importance of one such approach has been widely used by the first author in all his earlier works (Reproportioning of concrete mixes using generalised Abram's law)[6-10]. It is very interesting to note that the discusser has suggested one such rational approach which uses the cementing efficiency factor (k) of RHA and Bolomey's equation for compressive strength of concrete. Authors do agree that this method is also well established and accepted method of mix design especially for concrete with mineral admixtures. Discusser has applied this method using the authors' experimental results and demonstrated the applicability of the method. Authors thank the discusser for giving the detailed calculations and the various steps involved in the method. This will greatly help the readers and researchers to think deeply on these methods for further study. A similar discussion by the same discusser on the earlier work of the author is worth mentioning at this stage[11]. The study made by the discusser depends mainly on the 'k' values. Discusser has used some assumed values of 'k' based on his experience. As rightly pointed by the discusser, there is a need to estimate a reasonable value of 'k' which can be based on previous experience or obtained from specifically conducted tests on concretes with and without RHA. Authors appreciate the effort made by the discusser for various computations and generating table of results for supplementing the authors reported results.

The authors thank the discusser for suggesting a modified equation for fixing the w/c ratio to get the desired strength of concrete. The authors will definitely use this equation in their future work.

Dr. M.C. Nataraja
Professor, Civil Engineering Department,
Sri Jayachamarajendra College of Engineering,
Mysore 570 006

References

1. _______*Specification for 53 Grade Ordinary Portland Cement*, IS 12269 : 1987, Bureau of Indian Standards, New Delhi.
2. _______ *Recommended Guidelines for Concrete Mix Design*, IS 10262 : 1982, Bureau of Indian Standards, New Delhi, 1983.
3. Neville, A. M., Properties of Concrete, Fourth and Final Edition, Pearson Education, 2003.
4. Mehta, P.K., *Concrete - Structure, Properties and Material*s, Prentice Hall Inc, Englewood cliffs, New Jersey, 1985.
5. ______*Recommended practice for selecting proportions for normal, heavy weight, and mass concrete*, ACI Committee 211.1, ACI Manual of Concrete Practice, 2006.
6. Nagaraj, T.S., Sashi Prakash, S.G. and Raghuprasad, B.K., Re-proportioning Concrete Mixes, *ACI Materials Journal*, January-February 1993, Vol. 90, No. 1, pp 50-58.
7. Nataraja, M.C., Nagaraj, T.S. and Ashok Reddy, Proportioning concrete mixes with quarry waste, *International Journal of Cement, Concrete and Aggregates*, ASTM, USA, December 2001, Vol. 23, No. 2, pp. 1-7.
8. Nataraja, M.C., Nagaraj, T.S., Das, Lelin and Sandeep, N. Richard, Exploiting potential use of partially - deteriorated cement in concrete mixtures, *International Journal on Resources, Conservation & Recycling*, USA, Online doi:10.1016/j.resconrec.2006.10.004.
9. Nagaraj, T. S and Zahida Banu, A.F., Generalisation of Abram's law, *Cement and Concrete Research,* Vol. 26, No. 6, 1996, pp. 933- 942.
10. Girish Raj Urs, Nataraja, M.C., and Nagaraj T.S, Re-proportioning concrete mixtures for rapid production of pre-cast units, *The Indian Concrete Journal*, April 2006, Vol. 80, No. 4, pp. 40-44.
11. Girish Raj Urs, Nataraja, M.C. and Nagaraj T.S, Authors reply in Discussion Forum on paper titled, 'Reproportioning concrete mixtures for rapid production of precast units', *The Indian Concrete Journal*, July 2006, Vol. 80, No. 7, pp. 10-12.

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