Effect of supplementary cementitious materials on the strength and durability properties of recycled aggregate concrete

Discussion by M.C. Nataraja

Replies by *M. Manjunath and K.B. Prakash*

READER'S QUERY

This has reference to the paper titled 'Effect of supplementary cementitious materials on the strength and durability properties of recycled aggregate concrete', authored by M. Manjunath and K.B. Prakash, published in The Indian Concrete Journal (September 2016, Vol. 90, No. 9, pp. 41-48).

The paper deals with the effect of supplementary cementitious materials (SCM) on the properties of concrete produced by replacing natural coarse aggregates by recycled aggregates. The supplementary cementitious materials considered are silica fume (SF), metakaolin (MK) and ground granulated blast furnace slag (GGBS) at 10% partial replacement to cement. The fresh and hardened properties of concrete are investigated for various percentage replacements of recycled aggregates. Test results indicate that the strength properties and durability properties of recycled aggregate concrete can be improved through the use of SCM. I congratulate the authors as the paper is well written and has good research findings and useful to many researchers and readers. However the paper needs many clarifications from the point of practical application which are mentioned below and seek explanations from the authors.

It has been found that the workability of concrete with natural and recycled aggregate is almost the same as water saturated surface dry recycled aggregates are used. In addition the compressive strength of concrete mainly depends on the quality of recycled aggregate. The specific gravity, bulk density, water absorption of aggregates and its surface characteristics are the important ones. As reported in the literature, if good quality recycled aggregates are used for the production of new concrete; the recycled aggregate has no influence on the compressive strength, regardless of the replacement ratio of natural coarse aggregate with recycled aggregate. The same findings are found in literature for concrete tensile strength namely splitting and flexural tensile strengths as well. The modulus of elasticity of concrete may decreases with increasing recycled aggregate content as the specimen experiences higher deformation at any stress level. In addition lower modulus of elasticity of recycled aggregate compared to natural aggregate might

cause further reduction in the modulus of elasticity of concrete. In addition, shrinkage of recycled aggregate concrete depends on the amount of recycled concrete aggregate and the quality of mortar adhered on to the surface. Concrete with more than 50% of recycled coarse aggregate has significantly more shrinkage compared to concrete with natural aggregate. Many of these points are well reported in the literature. Following are some of the points that need clarification by the authors.

1. The workability reported in Table 2 of the paper for all concretes ranges from medium to low. For concrete without SCMs and for any percentage of RCA, the slump is between 80 to 95 mm which indicates that the concretes have medium workability. As the aggregates are pre-wetted and also as reported in several papers, the workability will not change much. Whereas in case of 10% SF and 10% MK case, the slump has decreased drastically to about 50 mm. This is mainly due to additional water requirement of SF or MK. As the water is kept constant, the slump has decreased from medium to low. Generally up to about 5% of SF or MK, no extra water is required to maintain the slump. As these concretes are different due to change in workability, comparison of strength among them is questionable.

AUTHOR'S REPLY

We thank the reader for having sent his comments and suggestions. Based on the available literature and the scope of our work, we have attempted to reply to the queries and comments and we gladly accept the suggestions.

Previous work have indicated that the use of recycled aggregate result in reduction in both workability and strength of concrete. However the workability can be improved with the use of certain superplasticizers. The main objective of the study was to compare the effect of SCMs and improve upon the strength characteristics which are evident from the results.

2. The workability reported in Table 2 as 91.5 mm (all values are measured to an accuracy of 1 mm) is not serving any purpose practically as all concrete are medium workable. As per IS 456:2000, the range of slump from 50 to 100 mm represents medium workable concrete. In addition slump should be recorded to an accuracy of 5 mm to 10 mm. As per the literature, the slump is measured to the nearest 5 mm if the slump is <100 mm and measured to the nearest 10 mm if the slump is >100 mm. Similarly the compacting factor should be measured and stated to nearest second decimal place such as 0.92, as per IS 1199:1959 (reaffirmed 2004).

Reply. It is true that the concrete has medium workability and the accuracy of recording slump is up to 5 mm and compaction factor to be measured to nearest second decimal. Since the workability was to be measured for the different concrete mixes with recycled aggregate replacement at 10% increment, the workability results were likely to be very close. Hence the workability through slump was measured with a dial gauge setup which has resulted in higher accuracy.

3. Authors have compared the strength of concrete with RCA in spite of the fact that the workability of concretes with RCA was different. Such a comparison is not yielding any qualitative results as the workability is different. The authors should have maintained the workability of both the concretes to be same by adding certain dosage of chemical admixtures (P or SP) to bring the workability of both concrete to same level so that strength results can be compared.

Reply. As mentioned earlier, the main objective of the research was to study the effect of SCMs in recycled aggregate concrete, the mix proportion is kept uniform. The addition of superplasticizer will improve the workability of the concrete mixes with recycled aggregate, but comparison of the strength properties with the reference concrete (without superplasticizer) may not be justified.

4. Use of 10% silica fume or metakaoline in RCA concrete of grade M20 with w/c ratio of 0.5 is again uneconomical and not going to improve the durability properties to a greater extent. I agree that the water absorption and sorptivity have decreased to certain extent compared to control concrete. The order of difference in strength of both concretes is about 10 to 15%. Keeping in mind the advantages derived from 10% of SF or MK, the mix appears to be highly uneconomical.

Reply. As expressed by various researchers, recycling of concrete waste is necessary from the view point of environmental preservation and effective utilization of resources. In this background, the economy achieved through the use of recycled aggregate and industrial wastes like SF and GGBS is difficult to measure. However an attempt may be made on this aspect.

5. Instead of 10% of SCMs, the authors should have decreased the water and hence the w/c by 10 to 20%. This results in substantial reduction in workability of RAC concrete. In order to enhance the workability to any level, certain dosage of SP (0.5 to 1%) could have been added. The resulting concrete will have much higher strength compared to the control concrete. As the w/c ratio is reduced, the concrete will definitely have much lesser water absorption and sorptivity.

Reply. We agree that the strength of RAC can certainly be enhanced through reducing the amount of water and compensating through the use of SP. But the objective of the present study was to utilize SCMs mainly the industrial wastes like SF and GGBS in making RAC having a medium workability.

6. The durability properties to be addressed are the RCPT, creep, shrinkage, alkali-aggregate reaction and other related tests in addition to water absorption and sorptivity. From this the contribution of SF ad MK can be studied effectively.

Reply. The durability studies in the form of absorption and sorptivity tests conducted in the present work using SCMs in RAC have given good results. Other durability tests like RCPT, creep, shrinkage, alkali-aggregate reaction and acidic and alkaline media attack are necessary.

7. The reduction in strength of concrete with RAC is mainly due to the inferior quality of mortar adhere to the surface which had led to inferior bond. If this bond is poor, than the concrete will have low strength and higher absorption capacity. This will result in less modulus of elasticity and more shrinkage. In order to address this issue, many authors are going for pressure washing of RCA. This is done so as to remove most or complete mortar adhered on to the aggregates. The pressure at which water is applied depends on the grade and quality of parent concrete. Washing for about 15 to 20 minutes at 3 to 4 MPa pressure cleans the aggregates to a considerable extent. Whether the authors have tried any such washing of RCA before use?

Reply. The recycled aggregates used in the present work are not subjected to any pressure washing.

8. In one of the conclusions the authors says 'With the addition of silica fume (as a partial replacement of cement by 10%), it is possible to replace natural coarse aggregates by recycled aggregates up to 50%, without affecting the strength and durability properties of concrete (Table 3.28). In fact from the Table it can be seen that the compressive strength even for 90% RCA is close to 26 MPa compared to 28 MPa of control concrete. It is the range of acceptable strength rather than the strength based on numerical value. It appears that the RCA can be used up to 90% without affecting the various strengths significantly.

Reply. The conclusion made i.e. 'With the addition of silica fume (as a partial replacement of cement by 10%), it is possible to replace natural coarse aggregates by recycled aggregates up to 50%, without affecting the strength and durability properties of concrete' is with respect to the comparison of the durability and strength properties of the reference concrete (0% RA), and in the case of RAC with SF it is observed that the flexural strength beyond 50% replacement of RA is lower than that of reference concrete, hence the conclusion.

– Queries by **Dr. M.C. Nataraja,** Professor of Civil Engineering and Head, Department of Construction Technology and Management, JSS Science and Technology University, Formerly SJCE, Mysore 570 006.

– Replies on behalf of both authors, by **M. Manjunath**, Associate Professor, Department of Civil Engineering, KLE Dr. M.S. Sheshgiri College of Engineering and Technology, Belagavi, Karnataka.