Two-Stage Mixing Approach(TSMA) Versus Normal Mixing Approach(NMA) For Concrete in Terms of Compressive Strength And Carbonation Depth

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Abstract— One of the major challenges of our present society is the protection of environment. Some of the important elements in this respect are the reduction of the consumption of energy and natural raw materials and consumption of waste materials. These topics are getting considerable attention under sustainable development nowadays. The use of recycled aggregates from construction and demolition wastes is showing prospective application in construction as alternative to primary (natural) aggregates. It conserves natural resources and reduces the space required for the landfill disposal[9]. A new concrete mixing method, that is the two-stage mixing approach (TSMA), was developed to improve the quality of RA concrete (RAC) by splitting the mixing process into two parts. The current paper describes the variation of compressive strength and carbonation depth by experimental analysis involving the modified mixing method with some amendments to the two-stage mixing approach by proportioning ingredients with the percentage of recycled coarse aggregates (RCA) and fly ash. Based on experimental works and results, improvements in strength to RAC were achieved with TSMA. The current paper describes the variation of compressive strength and carbonation depth by analyzing experimentally involving the modified mixing method with some amendments to the two-stage mixing approach by proportioning ingredients with the percentage of recycled coarse aggregates (RCA) and fly ash.

Key words: recycle, concrete, fly ash, recycled aggregate, Corbonation, Two-stage mixing approach(TSMA), Normal mixing approach(NMA).

I. INTRODUCTION

As sustainability is a pressing issue all over the world, the word **"**recycle**"** forms one of the most important key words today. Recycling and resource saving have been advocated in the construction industry, but the effectiveness of these has been constrained because the conditions in applying these approaches were not provided.Recovery of materials from the wastes can reduce the consumption of landfill areas and natural gravel resources.Although the recycling rate is high in some countries, the use of recycled aggregate (RA) is confined to low-grade applications, for higher grade applications, new recycling technology needs to be developed.

When structures made of concrete are demolished or renovated, concrete recycling is an increasingly common method of utilizing the rubble. Concrete was once routinely trucked to landfills for disposal, but recycling has a number of benefits that has made it a more attractive option in this age of greater environmental awareness, more environmental laws, and the desire to keep construction costs down. Moreover, there are a variety of benefits in recycling concrete rather than dumping it or burying it in a landfill.

(1) Keeping concrete debris out of landfills saves landfill space.
(2) Using recycled material as gravel reduces the need for gravel mining.
(3) Recycling one ton of cement could save 1,360 gallons (5.14 m^3) water, 900 kg of CO_2.
(4) Using recycled concrete as the base material for roadways reduces the pollution involved in trucking material.

To achieve sustainable issue in construction area, researchers and companies focus on using waste concrete as a new construction material. It is called recycled aggregate (RA) which can be produced by concrete crushers. Although using recycled aggregates has great opportunity to preserve healthy environment, the properties and characteristics of recycled aggregates has not been fully investigated yet.Since it is hard to standardize the characteristic of recycled aggregates, all the researchers who study recycled aggregate should perform experiment of their concrete, which will be used for recycled aggregate, to gain the characteristics of their specimens. The characteristic of recycled aggregates could be different by its parent concrete because the parent concrete was designed for its purposes such as permeable, durable and high strength concrete. Carbonation is a major cause of concrete structures deterioration leading to expensive maintenance and conservation operations. The eco-efficient construction agenda favours the increase of the use of supplementary cementing materials (SCMs) to reduce Portland cement**'**s consumption and also the use of recycled aggregates concrete (RAC) in order to reduce the consumption of primary aggregates and to avoid landfill disposal of concrete waste[11]. Carbonation depth tells the extent to which corrosion has reached towards the reinforcement steel member of an existing building. Carbonation when tested for concrete specimen tells the extent of carbonation at different ages of the specimen. The paper presents a comparison of the compressive strength and carbonation depth of the concrete made through NMA and TSMA.

II. LITERATURE REVIEW

Tam V.W.Y et al(2005)[10], gave a method of modified mixing of concrete. The scientists observed that the poor quality of RAC resulted from the higher porosity, higher water absorption, weaker interfacial transition zone (ITZ) between new cement mortar and Recycled Aggregates(RA) alters the application of RAC for higher grade applications. In the study, the two-stage mixing approach is provided to strengthen the weak link of RAC, which is located at the (ITZ) of the RA. The two-stage mixing approach gives a way for the cement slurry to gel up the RA, providing a stronger ITZ by filling up the cracks and pores within RA. From the laboratory experiments, the compressive strengths have been improved. This two-stage mixing approach can provide an effective method for enhancing the compressive strength and other mechanical performance of RAC, and thus, the approach opens up a wider scope of RAC applications.

Yong P.C and Teo D.C.L(2009)[13], said that the Recycled Aggregate Concrete (RAC) can achieve high compressive strength, split tensile strength as well as flexural strength. RAC has higher 28-day compressive strength and higher 28-day split tensile strength compared to natural concrete whereas the 28-day flexural strength of RAC is lower than that of natural concrete. Recycled Coarse Aggregate(RCA) shows good potential as coarse aggregate for the production of new concrete.

Flower D, and Sanjayan J.(2007)[2], quoted that Projections of global demand of the main binder of Portland cement, concrete structures, show that in the next 40 years concrete production will keep on rising. Portland cement production represents 74–81% of the overall CO_2 emissions of concrete, while aggregates production represents 13–20%. Portland cement's CO_2 emissions result from the calcination of limestone ($CaCO_3$) and from the combustion of fossil fuels, including the fuels required to generate electricity in power plants.

Patil S.P et al(2013)[8], concluded that the compressive strength of concrete containing 50% RCA has strength in close proximity to that of normal concrete. Splitting Tensile test shows that concrete has good tensile strength when replace upto 25-50%. The strength of concrete is high during initial stages but gradually reduces during later stages. Water absorption of RCA is higher than that of natural aggregate. Thus the usage of RCA in concrete mixture is found to have strength in close proximity to that of natural aggregate and can be used effectively as a full value component of new concrete.

Illston J.M(1994)[5], proved that Reinforcement corrosion is a major cause of the deterioration of concrete structures. Carbonation is recognized as a significant factor in this corrosion process. The basic mechanism involves atmospheric carbon dioxide that reacts with components of the hydrated cement and destroys its alkalinity.

According to Bendapudi S.C.K and Saha P(2011)[1], a primary goal is the reduction in use of portland cement, which can be easily achieved by partially replacing it with various cementitious materials. The best known of such materials is fly ash, a residue of coal combustion, which is an excellent cementitious material. In India alone, we produce about 75 million tons of fly ash per year, the disposal of which has become a serious environmental problem. The effective utilization of fly ash in concrete making is, therefore, attracting serious considerations of concrete technologists and government departments. The new Indian Standard on concrete mix proportions (IS:10262-2009) are already incorporated fly ash as a supplementary material to cement. Fly ash replacement of cement is effective for improving the resistance of concrete to sulfate attack expansion. The higher is the compressive strength of concrete, the lower is the ratio of splitting tensile strength to compressive strength. Finally, this literature search showed that the properties of concrete are enhanced when the substitution of Portland cement and aggregate was done by fly ash.

It is crucial that the environmentally driven options do not compromise the durability of reinforced concrete structures. Less durable concrete structures require frequent maintenance and conservation operations or even its entire replacement, which is associated with the consumption of more raw materials and energy. The importance of concrete durability in the context of eco-efficient construction has been rightly put by Mora E, (2007)[7], when he states that increasing the durability of the concrete from 50 to 500 years would mean a reduction of its environmental impact by a factor of 10.

Carbonation is a major cause of concrete structures deterioration. Concrete carbonation is a process by which atmospheric carbon dioxide reacts with the cement hydration products to form calcium carbonate. The importance of this phenomenon is related to the fact that it reduces the alkalinity of the concrete to a pH near 8. Since the steel passivation layer, an iron oxide layer that protects the steel from corrosion, needs a pH between 12 and 14. Hobbs D.W, (1988)[4] suggested that 9.5 is the pH threshold value for depassivation, the carbonation phenomenon can be responsible for the steel depassivation thus leading to corrosion.

Vyas C.M and Pitroda J.K(2013)[12], worked on the combination of RCA and Fly Ash and concluded that the applications of RCA inthe construction area are very wide. The main aim of using RCA isto reduce the use of natural resources. Another improving method is using the Fly ash in the recycled coarse aggregate mixing. Application of fly ash in the RCA concrete can improve the durability of the recycled coarse aggregate concrete. The use of fly ash could improve the strength characteristic of RCA concrete.

Marthong C and Agrawal T.P(2012)[6], stated that the normal consistency increases with the increase in the grade of cement and fly ash content. Setting time and soundness decreases with the increase in grade of cement. Use of fly ash improves workability of concrete and workability increases with the decreases in the grade of cement. Bleeding in fly ash concrete(FAC) is significantly reduced and other properties like cohesiveness, pumping characteristics and surface finish are improved, Gambhir[3]. Compressive strength of concrete increases with grade of cement. As the fly ash contents increases in all grades of Ordinary Portland Cement(OPC) there is reduction in the strength of concrete. The rate of strength gain of concrete with age is almost similar in all the three grades OPC. Concrete with 20% fly ash content closer to that of ordinary concrete at the age of 90 days. In all grades OPC, fly ash concrete is more durable as compared to OPC concrete and fly ash upto 40% replacement increase with grade of cement. Shrinkage of fly ash concrete is similar to the pure cement concrete in all grades of OPC.

III. MATERIALS USED

A. Cement:

Ordinary Portland cement of 43 grade satisfying the requirements of IS: 8112-1989. The specific gravity of cement was 3.005.

B. Fine aggregates:

The sand generally collected from haryana. Sand is the main component of grading zone-I of IS: 383-1978 was used having specific gravity of 2.62 and water absorption of 1 % at 24 hours

C. Coarse aggregates:

Mechanically crushed stone from a quarry situated in haryana with maximum size as 20 mm, satisfying to IS: 383-1978 was used. The specific gravity was found to be 2.63 and water absorption is 0.5 % at 24 hours. 4.Recycled coarse aggregates Aggregates obtained by the processing of construction and demolition waste are known as recycled aggregates.
Process of recycling is shown as follows

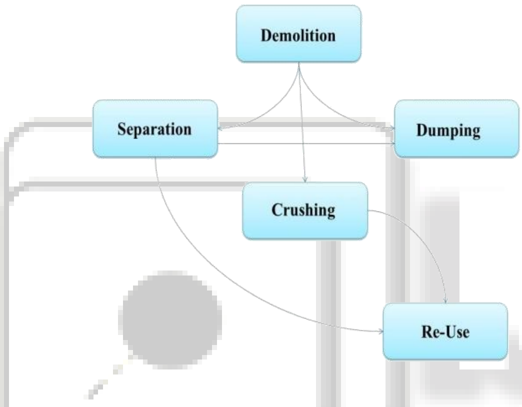

Fig. 1: Coarse Aggregrates

RCA for the experimental analysis was procured from the C & D waste plant in Delhi which is in collaboration with Municipal Corporation Of Delhi.

D. Fly Ash:

Fly ash is used as partial replacement of cement which replaces 10% of total cementitious material in all the cases of the experiments. Class F fly ash is used from haryana having specific gravity as 2.4 and satisfying IS 3812-1999.

Methodology

NMA follows certain steps. First, coarse and fine aggregate are mixed. Second, water and cementitious materials are added and mixed. However, TSMA follows different steps. First, coarse and fine aggregates are mixed for 60 seconds and then half of water for the specimen is added and mixed for another 60 seconds. Second, cementitious material is added and mixed for 30 seconds. Thirdly, the rest of water is added and mixed for 120 seconds.

The specific procedure of TSMA creates a thin film of cement slurry on the surface of RA which is expected fill the old cracks and voids. Pollution involved in trucking material can be reduced by using recycled concrete as the base material for roadways.

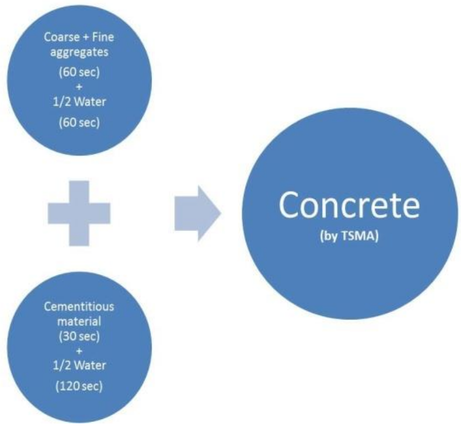

Fig. 2: Fly Ash

IV. EXPERIMENTAL OBSERVATIONS

Following table shows the experimental observations of the test samples made from TSMA and nominal mix by NMA.

(1) M-25(10-25) signifies the specimen mix having 10% fly ash and 25% RCA content.
(2) M-25(10-50) signifies the specimen mix having 10% fly ash and 50% RCA content.
(3) M-25(10-25) signifies the specimen mix having 10% fly ash and 75% RCA content.
(4) M-25(10-25) signifies the specimen mix having 10% fly ash and 100% RCA content.

S. No.	Specimen	COMPRESSIVE STRENGTH	
		7th day (MPa)	28th day (MPa)
1	Nominal M-25	17.84	31.7
2	M-25(10-25)	18.81	33.77
3	M-25(10-50)	20.21	32.88
4	M-25(10-75)	22.51	32.88
5	M-25(10-100)	15.10	27.99

Table 1: Experimental observations

These observations can be depicted in graphical form as follows :

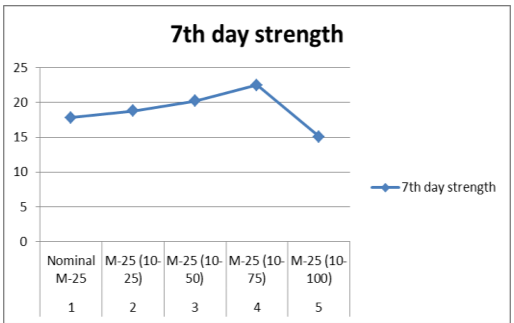

Fig. 4: Chart 1 7th day strength

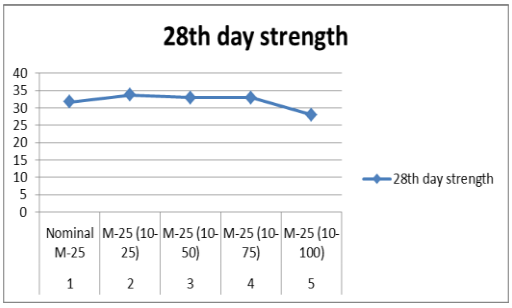

Fig. 4: Chart 2 28th day strength

S. No.	Specimen	Carbonation Depth (in mm)
1	Nominal M-25	5.0
2	M-25 (10-25)	3.5
3	M-25 (10-50)	4.0
4	M-25 (10-75)	8.5
5	M-25 (10-100)	10.5

Table 2: Experimental observations

These observations can also be depicted in graphical form as follows :

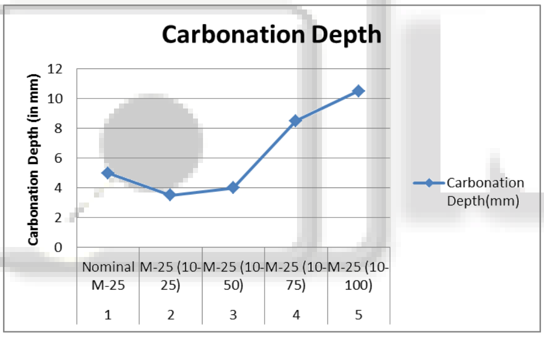

Fig. 5: Chart 3 : Carbonation Depth

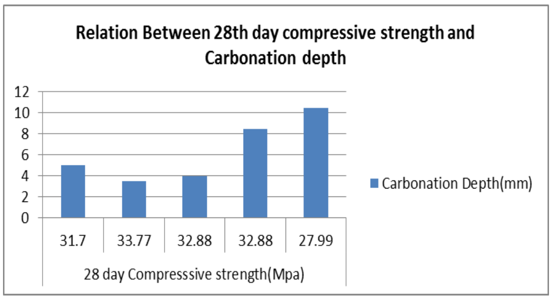

Fig. 6: Chart 4 : Relation between Compressive strength Carbonation depth

V. RESULTS AND CONLUSION

A. Results:

The above experimental analysis provides us with the following results:

(1) The compressive strength of M-25 grade nominal concrete made by NMA gives 7 day and 28 day strengths as 17.84 MPa and 31.7 MPa respectively and carbonation depth of 5.0 mm.

(2) Using TSMA, addition of 10% fly ash, the specimen made by 25% RCA gives 7 day and 28 day strengths as 18.81 MPa and 33.77 MPa respectively and carbonation depth of 3.5 mm..

(3) Using TSMA, addition of 10% fly ash, the specimen made by 50% RCA gives 7 day and 28 day strengths as 20.21 MPa and 32.88 MPa respectively and carbonation depth of 4.0 mm.

(4) Using TSMA, addition of 10% fly ash, the specimen made by 75% RCA gives 7 day and 28 day strengths as 22.51 MPa and 32.88 MPa respectively and carbonation depth of 8.5 mm.

(5) Using TSMA, addition of 10% fly ash, the specimen made by 100% RCA gives 7 day and 28 day strengths as 17.10 MPa and 27.99 MPa respectively and carbonation depth of 10.5 mm.

B. Discussion:

The specimen mix M-25(10-25) shows an increase of 5.46% in 7 day compressive strength and 6.52% in 28 day strength along with the decrease in carbonation depth by 30%, whereas, specimen mix M-25(10-50) shows an increase of 13.32% in 7 day compressive strength and 3.72% in 28 day strength with respect to nominal mix specimen along with the decrease in carbonation depth by 20% mm.

The specimen mix M-25(10-75) shows an increase of 26.17% in 7 day compressive strength and 3.72% in 28 day strength along with the increase in carbonation depth by 70%, however, specimen mix M-25(10-100) shows decrease of 15.10% in 7 day compressive strength and 11.70% in 28 day strength with respect to nominal mix specimen along with the increase in carbonation depth by 110%.

From 28 day strength and minimum carbonation depth point of view, specimen M-25(10-25) shows optimum increase in strength i.e 6.52% along with the minimum carbonation depth that is reduced by 30% with respect to nominal mix specimen.

C. CONCLUSION:

Following can be concluded from the experimental analysis that concrete made by replacement of 25% and 50% RCA and addition of 10% fly ash using TSMA gives more compressive strength for both 7 day and 28 day strength along with the decrease in carbonation depth by 30% and 20% respectively than the referred nominal concrete specimen made by NMA.

However on using 75% and 100% RCA and addition of 10% fly ash using TSMA, the concrete shows decrease in compressive strength than the Nominal concrete along with the increase in carbonation depth by 70% than the referred nominal mix specimen made by NMA.

Maximum 28 day strength is obtained by concrete made by using TSMA involving replacement of 25% RCA and addition of 10% fly ash. This concrete so made will be cost effective, strong as well as durable as it is reduced by 30% in carbonation depth as compared to the nominal mix specimen due to which rate of corrosion will be slower and it can be used in any constructional works in place of nominal concrete.

REFERENCES

[1] Bendapudi S.C.K and Saha P.(2011). 'Contribution of Fly Ash to the properties of Mortar and Concrete', International Journal of Earth Sciences and Engineering ,Vol. 4, 1017-1023.
[2] Flower D, Sanjayan J. Greenhouse gas emissions due to concrete manufacture. Int J Life Cycle Assess 2007;12:282–8.
[3] Gambhir M.L, 'Construction Technology ', Tata McGraw-Hill Education, 5th Edition 2013.
[4] Hobbs D.W. 'Carbonation of concrete in PFA.' Magazine Concr Res 1988;40:69–78.
[5] Illston J.M., Construction Materials, E&FN Spon, 2nd. Ed. 1994.
[6] Marthong C and Agrawal T.P.(2012). 'Effect of Fly Ash Additive on Concrete properties', International Journal of Engineering Research and Applications, Vol.2(4) 1986-1991.
[7] Mora E. Life cycle, sustainability and the transcendent quality of building materials. Build Environ 2007;42:1329–34.
[8] Patil S.P, Ingle G.S and Sathe P.D.(2013). 'Recycled Coarse Aggregates', International Journal of advanced Technology in Civil Engineering, Vol. 2(1), 27-33.
[9] Singh S.K, Sharma P.C,(2011). ' Use of recycled aggregates in concrete- A paradigm shift ', NBM Construction Portal.
[10] Tam V.W.Y et al.(2005). 'Microstructural analysis of recycled aggregates concrete produced from two-stage mixing approach', Cement and Concrete Research,Vol.35, 1195-1203.
[11] Torgal F.P(2012). 'An overview on concrete carbonation in the context of eco-efficient construction: Evaluation, use of SCMs and/or RAC', Construction and Building Materials 36 (2012) 141–150.
[12] Vyas C.M and Pitroda J.K.(2013). 'Fly ash and recycled coarse aggregate in concrete : New era for construction industries', IJETT Vol. 4(5), 1781-1786.
[13] Yong P.C and Teo D.C.L.(2009). 'Utilisation of recycled aggregate as coarse aggregate in concrete', UNIMAS E-Journal of Civil Engineering, Vol. 1 (1),1-6.

IS CODES :

[1] IS : 383-1978 Specification for coarse and fine aggregate from natural sources of concrete.
[2] IS: 8112-1989 43 grade Ordinary Portland Cement-Specifications.
[3] IS: 3812-1999 Specification for Fly ash to use as pozzolana and admixture.
[4] IS : 10262-2009 Concrete mix proportioning-guidelines(First Revision).