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Comparison of Flexural strength of concrete made by Two-stage mixing approach(TSMA) using fly ash and nominal concrete made by Normal mixing approach(NMA)

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Abstract— The largest synthesized material is concrete which has a per capita consumption of about 1.5 tons per annum in India. Concrete has the capacity to develop adequate engineering properties and to utilize locally available ingredients for a variety of applications, easily adapt to any size and shape and has comparatively low initial and maintenance costs. While concrete not being as big of an energy consumer as aluminum, structural steel and glass, concrete and particularly cement still remains a major energy 'sink' due to its volume of production and also environmentally unsustainable due to large quantities of CO_2 evolution associated with its manufacture. Raw materials for cement manufacture include non-renewable natural resources like lime stone, aggregates, manufactured sands (fine aggregates), and so on. Hence the Indian concrete Industry needs to take a good look at these challenges. The current paper describes the variation of flexural strength by experimental analysis involving the modified mixing method with some alteration 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 resulting in a denser aggregate and concrete.

Keywords— Keywords—concrete, recycled aggregates, cement, flexural strength, RCA, fly ash, Two-stage mixing approach(TSMA), Normal mixing approach(NMA).

I. INTRODUCTION

Sustainability is important to the well-being on our planet, continued growth, and human development. Concrete is one of the most widely used construction materials in the world. However, the production of Portland cement, an essential constituent of concrete, alone, leads to the release of significant amount of CO_2, a greenhouse gas (GHG). The production of 1 ton of Portland cement produces about one ton of CO_2 and other GHGs. The environmental issues associated with GHGs, in addition to natural resources issues, will play a leading role in the sustainable development of the cement and concrete industry during this century. Therefore, it is necessary to look for sustainable solutions for future concrete construction. A sustainable concrete structure is constructed in order to insure that the total environmental impact during its life cycle, including during its use, will be minimal [2]. Sustainable constructions have a small impact on the environment. They use “green” materials, which have low energy costs, high durability, low maintenance requirements, and contain a large proportion of recycled or recyclable materials. Green materials also use less energy, resources, and can lead to high-performance cements and concrete. The paper presents a comparison of the flexural strength of the concrete made through NMA and TSMA using fly ash as partial replacement of cement and recycled coarse aggregates(RCA) as partial replacement of natural coarse aggregates used in the production of concrete.

II. LITERATURE REVIEW

Tam V.W.Y et al(2005)[10], proposed the technique of modified mixing of concrete. They concluded that the higher water absorption and higher porosity results in poor quality of Recycled Aggregate Concrete (RAC). The weaker interfacial transition zone(ITZ) between Recycled Aggregates(RA) and cement mortar limits the application of RAC in higher grade applications. In the study, the TSMA provides strength to the weak link of RAC, which is located at the (ITZ) of the RA. In TSMA , cement slurry formed gels up with RA providing a stronger ITZ by filling up the cracks and pores within RA. Concrete made through TSMA shows improved compressive strength when tested in laboratory. This approach provides an effective method for enhancing the strength characteristics and other mechanical properties of RAC, and thus, opens a wider scope of applications.

According to Yong P.C and Teo D.C.L(2009)[12], the RAC can achieve high compressive strength, split tensile strength as well

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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.

In their research, Patil S.P et al(2013)[8], have concluded that the compressive strength of concrete containing 50% RCA has approximately similar strength to that of normal concrete. Splitting tensile test shows that concrete has good tensile strength when replace upto 25-50%. Initially the strength is high but gradually reduces during later stages. Water absorption of RCA is higher than that of natural aggregate. According to Bendapudi S.C.K and Saha P(2011)[1], a primary goal is a reduction in the use of portland cement, which is 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)[16] 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. Vyas C.M and Pitroda J.K(2013)[11], have worked on the combination of RCA and Fly Ash and have concluded that the applications of recycled coarse aggregate in the construction area are very wide. The main aim of using recycled coarse aggregate is to 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 recycled coarse aggregate concrete can improve the durability of the recycled coarse aggregate concrete. The use of fly ash could improve the strength characteristic of recycled coarse aggregate concrete. Marthong C and Agrawal T.P(2012)[7], have stated that the normal consistency increases with 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 the workability of concrete and workability increases with the decreases in the grade of cement. Bleeding in fly ash concrete is significantly reduced and other properties like cohesiveness, pumping characteristics and surface finish are improved, M.L Gambhir[4].

According to Kamala R. and Rao B. K(2012)[5], the results obtained shows that there is decrement in the Flexural strength of beams for 56 days. The maximum 28 days tensile strength was obtained with 40% replacement of crushed tile aggregates and the strength is more at 28 days of curing compared to the Normal cement concrete(NCC) mix.

Katz A.(2003)[6], by experimental analysis on the properties of concrete made with recycled aggregate from partially hydrated old concrete and two different types of cements showed that the difference in the quality of the two types of cement was clearly seen and the ratios of the flexural and the splitting strengths to the compressive strength values were within a reasonable range. The higher values of the flexural and splitting strengths relative to the predicted ones were clearly seen especially for the OPC recycled concrete. Smaller values than the predicted ones are expected for lightweight aggregate concrete.

The analysis done by Puri N., Kumar B. and Tyagi H.(2013)[9], shows that a significant increase in flexural strength was observed when natural aggregates were replaced with RCA. However a decrease in flexural strength was observed when natural aggregates were replaced with PVC aggregates. Very low flexural strength has been shown by concrete in which fine aggregates were replaced by pulverized leather waste.

As per the experimental work done by Deshpande N.K, Kulkarni S.S and Pachpande H.(2012)[3], For M25 grade concrete the flexural strength of nominal M25 grade concrete is 3.5N/mm^2. Conventional materials satisfies the requirement with 3.76N/mm2. Split tensile test and Flexural strength both are tests for tensile strength of concrete. Concrete made by using recycled aggregates showed slightly lower values of tensile strength as well as flexural strength, hence the loss in tensile strength should be considered while designing members using recycled aggregate concrete.

III. MATERIALS USED

A. *Cement:* Ordinary Portland cement of 43 grade satisfying the requirements of IS: 8112-1989[14]. The specific gravity of cement was found to be 3.005.

B. *Fine aggregates:* The sand generally collected from haryana. Sand is the main component grading zone-I of IS: 383-1978[13] was used with 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 20 mm maximum size, satisfying to IS: 383-1978[13] was used. The specific gravity was found to be 2.63 and water absorption is 0.5 % at 24 hours.

D. *Recycled coarse aggregates:* Aggregates obtained by the processing of construction and demolition waste are known as recycled aggregates. RCA for the experimental analysis was procured from the C & D waste plant in Delhi which is in collaboration with Municipal Corporation Of Delhi.

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E. *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[15]

F. *Methodology*

NMA follows the following steps:

1) First, coarse and fine aggregate are mixed.

2) Second, water and cementitious materials are added and mixed.

However,

TSMA follows different steps:

1) 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.

2) Second, cementitious material is added and mixed for 30 seconds.

3) Thirdly, the rest of water is added and mixed for 120 seconds.

The specific procedure of TSMA creates a thin layer of cement slurry on the surface of RA which is expected to get into the porous old mortar and fill the old cracks and voids. Using recycled concrete as the base material for roadways reduces the pollution involved in trucking material.

IV. EXPERIMENTAL OBSERVATIONS

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

A. M-25(10-25) signifies the specimen mix having 10% fly ash and 25% RCA content.

B. M-25(10-50) signifies the specimen mix having 10% fly ash and 50% RCA content.

C. M-25(10-25) signifies the specimen mix having 10% fly ash and 75% RCA content.

D. M-25(10-25) signifies the specimen mix having 10% fly ash and 100% RCA content.

Table 1: Flexural strength

S. No.	Specimen	7th day strength	28th day strength
1	Nominal M-25	2.63	3.68
2	M-25 (10-25)	2.84	3.96
3	M-25 (10-50)	2.71	3.67
4	M-25 (10-75)	2.54	3.53
5	M-25 (10-100)	2.26	2.98

Chart 1: 7th day Flexural strength

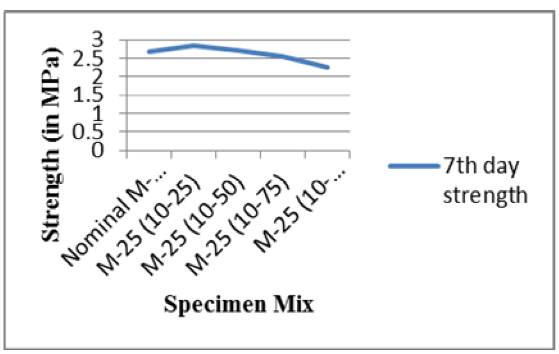
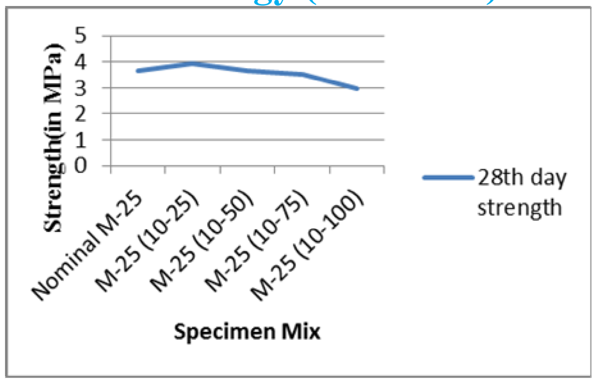
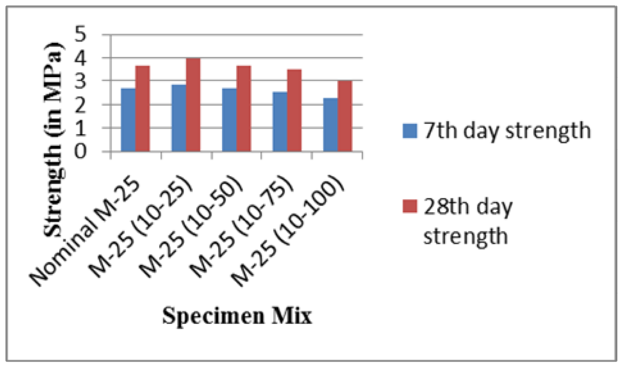


Chart 2: 28th day Flexural Strength





Graph : Flexural Strength (both 7th and 28th day)

V. RESULTS AND DISCUSSION

A. Results

The above experimental analysis provides us with the following results:

1) The flexural strength of M-25 grade nominal concrete made by NMA gives 7 day and 28 day strengths as 2.63 MPa and 3.68 MPa respectively
2) Using TSMA, addition of 10% fly ash, the specimen made by 25% RCA gives flexural strength at 7 day and 28 day as 2.84 MPa and 3.96 MPa respectively.
3) Using TSMA, addition of 10% fly ash, the specimen made by 50% RCA gives 7 day and 28 day flexural strengths as 2.71 MPa and 3.67 MPa respectively.
4) Using TSMA, addition of 10% fly ash, the specimen made by 75% RCA gives 7 day and 28 day strengths as 2.54 MPa and 3.53 MPa respectively.
5) Using TSMA, addition of 10% fly ash, the specimen made by 100% RCA gives 7 day and 28 day strengths as as 2.26 MPa and 2.98 MPa respectively.

B. Discussion

The specimen mix M-25(10-25) shows an increase of 7.98% in 7 day and 7.60% in 28 day flexural strength, however, specimen mix M-25(10-50) shows an increase of 3.04% in 7 day and a decrease of 0.27% in 28 day flexural strength with respect to nominal mix specimen.

The specimen mix M-25(10-75) shows a decrease of 3.42% in 7 day and 4.07% in 28 day flexural strength, whereas, specimen mix M-25(10-100) shows a decrease of 14.06% in 7 day and 19.02% in 28 day flexural strength with respect to nominal mix specimen. From 28 day strength point of view, specimen M-25(10-25) made by TSMA shows optimum increase in flexural strength i.e 7.60% with respect to nominal mix specimen made by NMA.

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VI. CONCLUSION

Samples after casting were tested and gave the above results depicted by chart 1 and 2. The outcome of this work reveals that concrete made by replacement of 25% RCA and addition of 10% fly ash using TSMA gives more flexural strength for both 7 day and 28 day strength than the referred nominal concrete specimen made by NMA however on using TSMA, on increasing RCA content to 50% and fly ash remaining constant 10%, concrete shows increase in 7 day flexural strength but shows decrease in 28 day flexural strength. On using TSMA, on increasing RCA content to 75% and 100% and fly ash remaining constant 10%, the concrete shows a decrease in flexural strength than the Nominal concrete.

Maximum 28 day flexural strength is obtained by concrete made by using TSMA involving replacement of 25% RCA and addition of 10% fly ash. This concrete so made is strong as well as cost effective and can be used in any constructional works in place of normal concrete.

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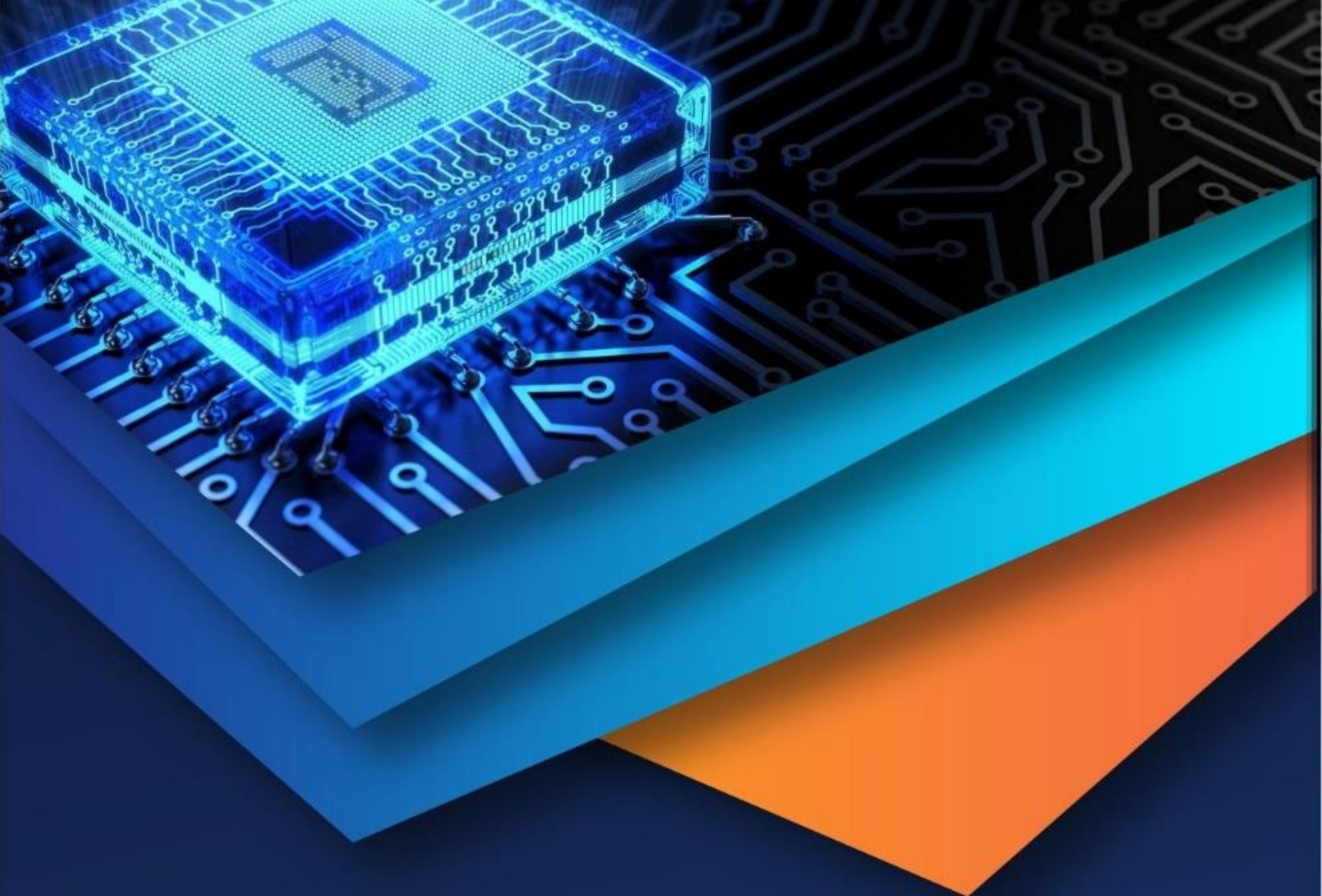
IS CODES :

[13] IS : 383-1978 Specification for coarse and fine aggregate from natural sources of concrete.

[14] IS: 8112-1989 43 grade Ordinary Portland Cement- Specifications.

[15] IS: 3812-1999 Specification for Fly ash to use as pozzolana and admixture.

[16] IS : 10262-2009 Concrete mix proportioning-guidelines(First Revision)



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