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Experimental investigation of Rheological and mechanical properties of concrete prepared with recycle fine aggregate

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Abstract: In this paper evaluates the possibility uses of recycled fine aggregate (RFA) obtained from C& D waste a substitute of natural fine aggregate (river sand) for development of sustainable concrete. For this, an experimental investigation of M30 grade of concrete is prepared by using of 20, 30, 50, and 100% replacement of NFA by RFA and compared their results with conventional concrete (0% RFA). Target strength 30 MPa and slump value 100 mm is set for each series of concrete mix. Flow properties of concrete such as workability and harden properties like compressive strength, flexural strength, split tensile strength and modulus of elasticity evaluated. Results shows that compressive strength, flexural strength, splitting tensile strength and modulus of elasticity reduces 8.63%, 6.32%, 6.25% and 8.75%, respectively in concrete made with 30% replacement of NFA by RFA at 28 days than that of conventional aggregate concrete. In terms of rheological and mechanical properties, the trend displayed by concrete is also very much similar to the conventional concrete. Finding from this experimental study suggest that the RFA has enormous potential to considerably reduce the cost of concrete.
Keywords: Recycled fine aggregate, Rheological, RC

1. INTRODUCTION

Most of civil engineering structure in India are either completed its design life or it is not constructed with proper design specification as a result of risk of life and property. Hence these structures required demolition (partially or fully) and maintenance which produces huge amount of demolition waste and required enormous amount of fresh aggregates. Also, Rapid construction in developing country like India required huge amount aggregate that prompts exaggeration of natural resources. Therefore, restriction on the application of natural aggregate is essential to maintain ecological balance. The concept reutilization of construction and demolition (C&D) debris in fresh construction is not new. Several studies have been conducted to application of recycle aggregate in manufacturing of new concrete. Wei wu et al. [2] studies the mechanical properties of high strength concrete produced with copper slag substitute as fine aggregate at different replacement ratio and found that up to 40 % substitution level give better mechanical properties but beyond that properties decreases significantly. Meizhuchen et al. [3] investigate the feasibility of recycle fine aggregate powder (RFAP) in asphalt mixture as filler and concluded that the RFAP improve some behavior of asphalt like water sensitivity and fatigue resistance and decreases temperature susceptibility. Fathifazl et al. [4] reported that creep and shrinkage behavior of concrete manufactured with recycle coarse aggregate by residual mortar factor method are similar or even less than that of entirely conventional aggregate concrete. Jian yang et al. [5] examine the physical and mechanical behavior of concrete with high substitution level of recycle concrete aggregate (RCA) and crushed clay bricks (CCB) and found that up to 20% inclusion of CCB not significant change in any properties but after that permeability of concrete remarkably increases. SC Kou et al. [6] studies the long-term mechanical behavior and pore structure of recycle aggregate concrete and concluded that when curing time more than 5-year compressive strength decreases while split tensile strength increases. WH kwan et al. [7] investigate the amount of replacement of recycle coarse aggregate and its durability properties and found that recycle aggregate concrete (RAC) possess better UPV value, less water absorption and less permeability and target strength is achieved even 80 % replacement level of recycle coarse aggregate by DoE method. J sim et al. [8] investigate the chloride ion penetration resistance and carbonation depth of recycle concrete having entirely recycle coarse aggregate and varying amount of recycle fine aggregate and fly ash and found that RAC have sufficient resistivity to chloride ion penetration and carbonation depth of recycled aggregate concrete. MN Soutsos et al. [9] reported that the demolition waste can be used for the development of new precast concrete product. TC Ling et al. [10] studies the utility of recycle glass in architectural cement mortar and conclude the increase in the amount of recycle glass workability and dry shrinkage properties enhanced while reduction in flexural and compressive strength. Elhakam et al. [11] examine the properties of concrete manufactured with recycle concrete aggregate and found that its strength characteristics and porosity decrease and to overcome this used three properties such as self-healing of recycle aggregate, mixing method and addition of silica flumes. Zhige et al. [12] investigate the influence of replacement of clay bricks powder in concrete on its mechanical behavior with orthogonal experimental design method and concluded that no significant reduction in mechanical properties of recycle aggregate concrete. SC Kou [13] investigate the consequences of class F fly ash inclusion in recycle coarse aggregate concrete and found that 25-35% inclusion of fly enhances the quality of recycle aggregate concrete. Benito mas et al. [14] reported that 40% replacement of recycle coarse aggregate satisfying all aspects of concrete for non-structure use. AuxiBarbudo et al. [15] analyze the use of super plasticizer in RAC development with 0,20, 50 and 100% replacement ratio and found that workability, density at fresh state and strength characteristics improved with the use of high-performance water reducing admixture. B safi et al. [16] investigate the feasibility of using polyethylene terephthalate (PET) as fine aggregate in manufacturing of self-compacting mortar with 0, 10, 20, 30, 50% and finds its physical, mechanical, and microstructural properties. Results reveals that 50 % replacement of PET give better physical and mechanical properties than the other substitution level. E Miren et al. [17] reported that recycle aggregate consist of 50% recycle fine aggregate. In this investigation recycle fine aggregate are used to manufactured control low strength materials (CLSM) bleeding, penetration resistance for loose state and density, porosity and water absorption in harden state are analyzed. Results shows that up to 30% inclusion of recycle aggregate gives acceptable properties of CLSM. Jian Geng [18] Studies the effect on carbonation resistance by replacement amount of RFA and fineness of RFA with addition of fly ash found that carbonation depth increases with increasing the RFA replacement ratio and carbonation resistance decreases with decreases in fineness vale of RFA. CA Issa [19] investigate the feasibility of applying recycled crumbled rubber in development of concrete with different replacement ratio and found up to 25% replacement yield acceptable compressive strength of RAC. Tao ji et al. [20] studies cracking resistivity of RAC with replacement level of RFA is 50% and constant water cement ratio including its moisture level of RFA and found that cracking resistivity of RFA concrete increases with increase in moisture level of RFA. WH Yung et al. [21] studies the durability properties of self-compacting concrete made with substitution of waste tire in place of fine aggregate in 5, 10, 15, 20% by volume and concluded that self-compacting rubber concrete has good sulphate resistance, high electrical resistivity and acceptable compressive strength. E Anastasiou et al. [22] investigate the feasibility of use of fly ash as binder, C&D waste as fine aggregate and steel slag as coarse aggregate and find strength and durability properties of concrete. Result reveals that these alternative materials can be used for low grade application. AG Khoshkenari et al [23] Reported that the both compressive and split tensile strength of RAC enhanced with addition of 0-2 mm fine aggregate. Sun-Woo Kim [24] A comparative study are done on the bond behavior of RFA concrete and conventional concrete using pullout test with deformed reinforced bar and found that there is not any reduction in bond strength up to 60% replacement ratio. Hyun Song [25] Introduce a hybrid method to improve the quality of recycle aggregate and produce self-compacting recycle concrete and tested its physical, mechanical and durability properties and concludes the treated recycle aggregate gives better results. TuhanBilir [26] investigate the consequences of substitution of fly ash as fine aggregate in cement mortar and find rheological and mechanical properties of mortar concluded that 60-70% of fly ash in mortar does not reduces any properties. SomayehLotfi et al. [27] used ADR process to get recycle aggregate and compare the mechanical and durability properties RAC having four substitution level 0, 20, 50, 100% with virgin concrete. Results reveals that high percentage level of recycle aggregate has minor impact on the properties of RAC. Haolinsu [28] analyze the effect of grading and size of waste rubber tyre in recycle aggregate concrete with 20 % replacement and compare its fresh and harden properties with conventional concrete and found that increasing the particle size of rubber increases the workability and fresh density. Chen-Chih Fan et al. [29] Reported that the recycling procedure and amount of replacement are important factor which controls properties of recycle aggregate concrete. Marco Pepe et al. [30] proposed a new mix design method which use the water absorption value of RCA to control the compressive strength. Peng Zhu et al. [31] reported that recycle powder contain unhydrated cement can be used partially in the place of cement. Sun Kim [32] investigate the influence of inclusion of cathode ray tube (CRT) scarp as fine aggregate on durability of RAC and concludes the increase in replacement ratio increases its freeze-thaw resistance, resistivity to sulphate attack, chloride ion penetration resistivity while decreases in compressive and flexural strength. Teijun Liu [33] studies the comparative behavior of 0, 30, 60 and 100% volumetric replacement of CRT with as fine aggregate and found that compressive strength and elastic modulus of concrete decreases with rise in substitution level while chloride ion penetration resistance increases.

In summary, various author studies the mechanical and durability behavior of RAC and reported that the mechanical and durability behavior of the RCA concrete is lesser than those of conventional concrete with NCA [12-13, 28, 32]. Also, high water absorption value of Recycle aggregate in contrast to Natural aggregate [29]. To overcome this draw back application of suitable water reducing admixture is essential.

The available research on concrete with RFA reflects that there is inadequate focused on mechanical fresh and hardened properties.

In the present investigation, the selections of the tests conducted were based on the literature gaps and the parameters which could normally estimate the feasibility of the use of these RFA in the mix of concrete. Thus, there is essential requirement of advance extensive research work on fresh and harden properties of concrete etc. in a sequential manner to assess the application of these types of in concrete production. In the current experimental investigation, NFA partly replaced by RFA at variable ratios and their effectiveness on the slump value and strength properties are evaluated. It is presented that the use of RFA in place of NFA in concrete as a replacement.

2. Experiment Schedule

2.1. Materials

2.1.1. Cement

Pozzolana Portland cement (PPC) conforming to the Indian IS specification mentioned in 1489 (part 1) 1991 used in mix design of concrete. The physical and mechanical properties of cement are presented in Table no 1.

2.1.2. Aggregates

In this experimental investigation three types of aggregates were used i.e., natural coarse aggregate (NCA), Natural fine aggregate (NFA), and RFA. NCA was manufactured by crushing of rocks, and NFA was extracted from river bed. RFA was extracted from recycling by the process of segregation, crushing, grading and washing. NFA and RFA were mixed with other constituent in the saturated surface dried (SSD) condition as per IS 383 (1970). The specific gravity and water absorption test of the aggregates were carried out as per IS: 2386 (part 3)-1963, and the fineness modulus was obtaining as per IS: 2386 (part 1)-1963. In this assessment, the water absorption of RFA was found 0.97%, which was higher than that of NFA. This absorption water is considered at the time of adjustment of total requirement water of mix design of concrete [35]. The physical properties of all fine aggregates are summarized in Table 2. The grading curves all aggregate was presented in Fig.1. The grading curves of the aggregates were fulfilling the specification of the standard grain size distribution curve as per IS: 2386 (part 1)-1963, IS: 460-1962. The physical and mechanical properties of NCA are as per IS: 2386(part – 1, 2, 3, & 4) as shown in Table 3.

2.1.3. Admixture

Poly-carboxylate ether super-plasticizer was used, having specific gravity 1.125 and based on third trail dosages about 0.85 percent of Cementous materials was required to achieving the target slump value of concrete.

2.2. Method

2.2.1. Mix proportion of concrete ingredients

The mix proportions for 30MPa grade of conventional and RFA concrete were planned by the adjustment in the substitution proportion of RFA to achieving target mean strengths 30 MPa along with slump value 100 mm for both NAC and RC. In this experiment investigation four substitution proportions (i.e., 20%, 30%, 50%, and 100% by weight) were used as per IS: 10262:2009 All mix constituents are mention in Table 4. Concrete with zero substitution proportion of RFA is term conventional concrete. The mix notation was demonstrating the as per substitution of RFA. All aggregates were used under the SSD condition and accordingly the viable W/C proportion was utilized in this investigation. A high slump was kept up for all the blending proportions by aligning these measures poly-carboxylate-based super-plasticizer (SP) were used. The binder and aggregate were blended in three phases. To start with, the fine and coarse aggregates were blended in dry condition for 30 s. Thereafter, the cement is included and blended for 30 s in dry condition. At long last, the wide range of various materials were included and blended for 90 s. This mixing approach gives dense concrete and improve the qualities of the reused aggregate concrete [1, 29].

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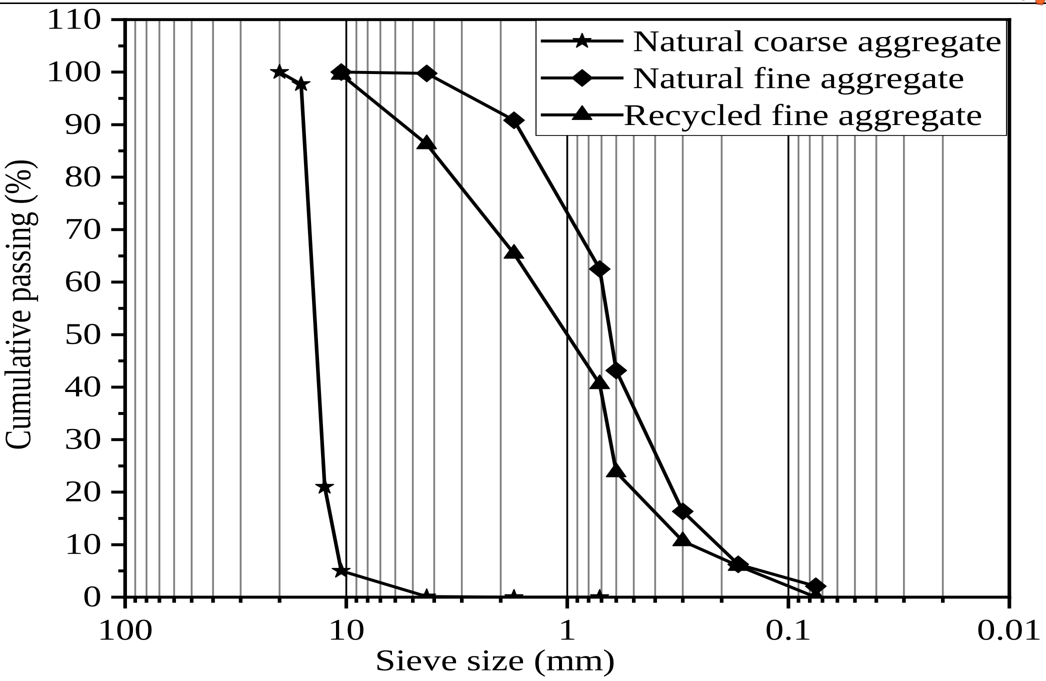

Fig.1.Grading of NCA, NFA and RFA

Fig. 2. Sources of C&D waste

Fig.3. Recycle and natural fine aggregate

Table 1.Properties of cement

Cement	Portland Pozzolana Cement (**PPC**) conforming to the IS 1489 (part 1) 1999
Specific gravity	3.12
Initial setting time as per IS 4031(Part 5)	120 min
Final setting time as per IS 4031 (Part 5)	300 min.
Fineness value IS 4031(Part 1)	6 percent
Soundness IS 4031(Part 3)	3.0 mm
Compressive strength, 3 day IS 4031(Part 6)	18.83 MPa
Compressive strength, 7 day IS 4031(Part 6)	28.52 MPa
Compressive strength, 28 day IS 4031(Part 6)	39.62 MPa
Standard consistency IS 4031:1988(Part 4)	33 percent

Table 2. Properties of fine aggregate

Sand	NFA	RFA
Specific gravity (IS 2386, Part 3)	2.622	2.47
Water absorption (IS 2386, Part 3)	0.2 %	0.97 %
Fineness modulus (IS 2386, Part 1)	2.72	2.84
Bulking of sand (IS 2386, Part 3)	16.17 %	19.26 %
Sand zone (IS 2386, Part 1)	II	II

Table 3. Properties of coarse aggregate

Coarse aggregate (20 mm)	Crushed stone
Texture	Rough
Specific gravity (IS 2386, Part 3)	2.74
Flakiness index (20 and 10 mm) (IS 2386, Part1)	18.5 & 19.5 %
Aggregate impact value (IS 2386, Part IV)	20.4 %
Aggregate crushing value (IS 2386, Part IV)	16.2 %
Los Angeles abrasion value (IS 2386, Part IV)	15.3 %
Water absorption value (IS 2386, Part 3)	0.82 %

Table 4. Mix proportion for M30 concrete

Mix notations	Water (kg/m^3)	Cement (kg/m^3)	NFA (kg/m^3)	RFA (kg/m^3)	CA (kg/m^3	SP (kg/m^3)	Remarks
M-30-RFA-0	161.67	375.98	686.96	0	1241.22	3.2	W/C=0.43
M-30-RFA20	161.67	375.98	549.57	129.43	1241.22	3.2	
M-30-RFA30	161.67	375.98	480.87	194.14	1241.22	3.2	
M-30-RFA50	161.67	375.98	343.48	323.57	1241.22	3.2	
M-30RFA100	161.67	375.98	0	647.14	1241.22	3.2	

2.2.2. Specimen preparation and curing

From each concrete mix to obtain the compressive strength, split tensile strength, flexural strength and elastic modulus, 45 cubes of 150 mm sides, 90 cylinders having diameter 150mm and length 300 mm, 45 prisms (150×150×700 mm) specimens were fabricated in each trail. After 24 hour the specimen creation, mould were removed and specimen were immersed in open water tank with temperature at 27 ± 1 ° for water curing. Each trail consists of three series of specimen and each series tested at the age of 7, 28 and 56 days after proper curing and average value were consider as the strength of that mix in specified period. All specimen casted in steel mould lubricating with oil and compacting using table vibrating.

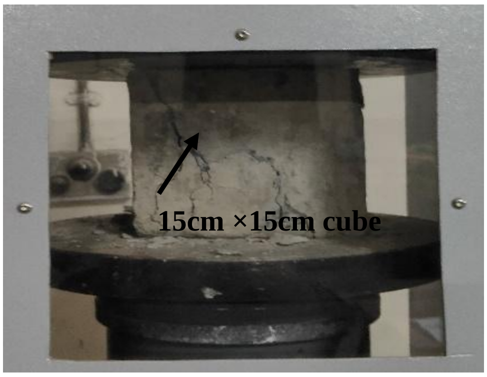

Fig.4. Test set up for compressive strength

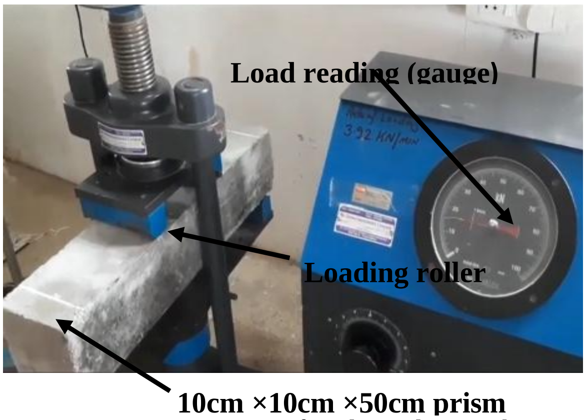

Fig.5. Test set up for Flexural strength

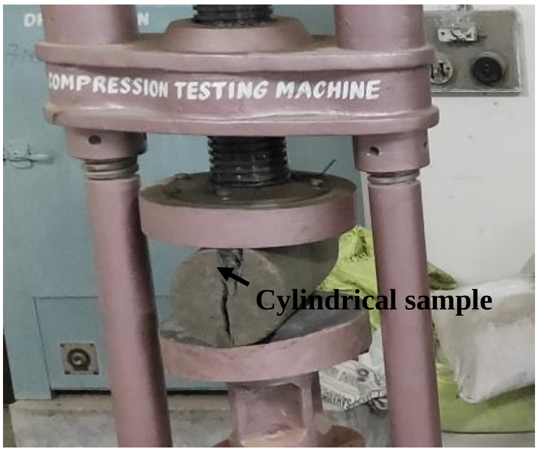

Fig.6. Test set up for splitting tensile strength

Fig.7. Slump value of fresh concrete mix prepared by 30 % replacement NFA by RFA(M-30-RFA30).

2.3. Testing of specimen

The compressive strength tests were carried out as per IS 516 (1959) at 7, 28, and 56 days with the set of three cubes. The application of load was started with the stacking rate inside the scope of 0.14 to 0.324 MPa/s utilizing a universal testing machine (UTM). The split tensile strength test was conducted at 7, 28 and 56 days as per IS 5816 (1999). A heap was applied with the stacking rate inside the scope of 1.2 MPa/min to 2.4 MPa/min using the UTM. The elastic modulus of concrete was tested at 7, 28, and 56 days as directed in IS 516 (1959). Two extensometer having gauge length 12.5 cm and strain accuracy of 2 x 10-6 are attached on the cylinder axially for measuring strain. The flexural strength test is conducted as per IS 516 (1959) at the age of 7, 28, 56 days with three specimens at each age by four-point loading.

3. Results and discussion

3.1. Workability of concrete

This examination led slump tests on concrete with different RFA substitution proportions as appeared in Table 4, slump declined with an expansion in substitution proportion. The specimen containing reuse aggregate introduced less slump than did conventional concrete when the two specimens shared indistinguishable water concrete proportions. This can be credited to the way that RFA has a harsher surface and more prominent rakishness, which builds the rubbing among the particles. In this way, as the RFA substitution proportion was expanded, the higher grouping of fine aggregate in the concrete glue created more erosion between the particles, accordingly decreasing slump in the concrete. The workability of new concrete can be estimated by slump in which a higher slump shows better workability. The workability of the concrete in this investigation was appeared to decay with an expansion in FRA substitution proportion. The values of this test fall between 85 mm and 105 mm. The maximum value obtained is around 105 mm for 0 % replacement and the minimum slump value was 85 mm for 100% replacement. But the optimum value of slump 95 mm attended on 20% replacement. Based on the trial and error the various proportions for M30 concrete mix were designed.

3.2 Compressive strength

The deliberate compressive strengths of concrete are appeared in Fig: - 9. These qualities are the mean acquired from three specimens of each mix proportion of concrete. The compressive strength of concrete specimens was tried at 7 days, 14 days, and 28 days. The test outcomes uncovered that, true to form, the compressive strength expanded with the expansion in restoring time. The strength of RFA concrete commonly diminished as the substitution proportion of RFA expanded. The compressive strength of reused concrete reductions 8.63% when the substitution proportion of RFA is 30% at 28 days. The compressive strength of RFA concrete diminished roughly 21.05% contrasted and that of virgin concrete when NFA was totally supplanted by RFA. In this way, it was seen that the expansion of the RFA substitution proportion didn't fundamentally lessen the compressive strength of concrete.

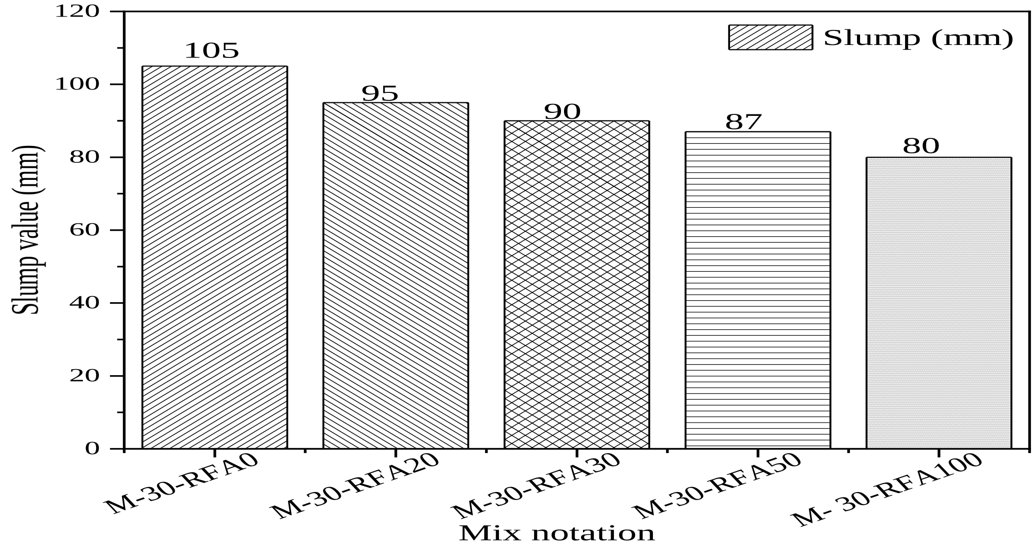

Fig.8.Slump value of concrete prepared with different replacement percentage of NFA by RFA

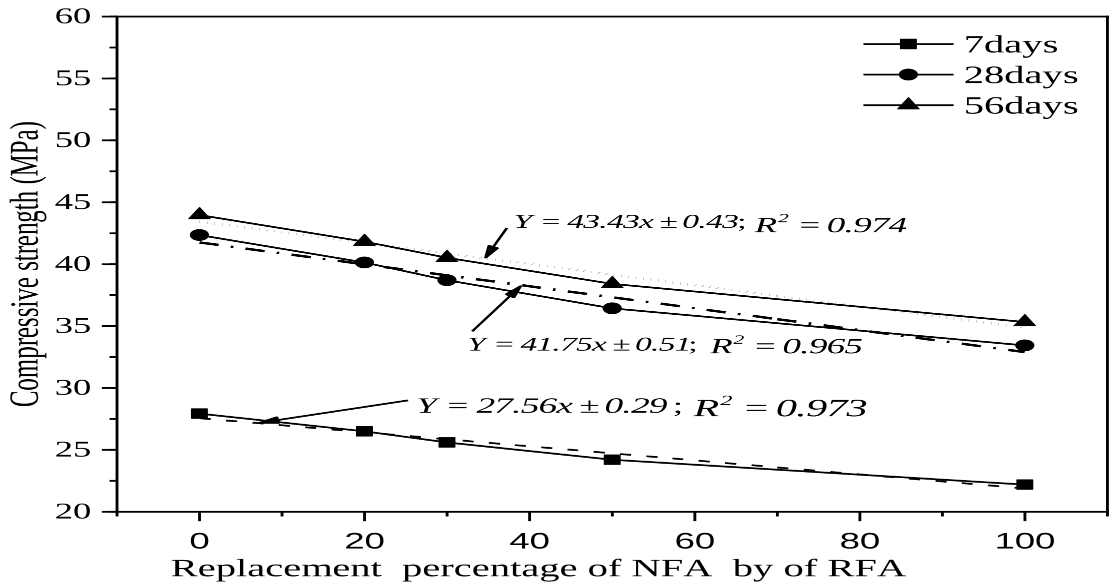

Fig. 9. Variation of compressive strength of concrete prepared by different percentage replacement NFA by RFA.

3.3 Flexural strength

The flexural strength of concrete tested at the age 7, 28, and 56 days with three specimens at each age of five different replacement ratio of RFA. Average of three specimen of each mix are presented in Fig: - 10 as flexural strength. From results it is revealed that the 30% replacement of RFA gives the better results 3.7 N/mm2 as compared to virgin concrete. Further rise in the substitution ratio of RFA flexural strength of concrete decreased at every age of concrete.

3.4 Split tensile strength

The consequences of the splitting tensile test are appeared in Fig: - 11. concrete displayed a decrease in the split tensile strength with the expansion in the substitution proportion of RFA, yet no critical change was apparent up to 30% substitution in RA concrete. These practices are like the compressive strength results. It was seen that, the measure of RFA didn't influence the tensile strength fundamentally, especially when the curing time was adequate, i.e., 56 days or more.

3.5 Static modulus of elasticity

To find the modulus of elasticity, the graphical relationship between compressive stress and strain was established. The elastic modulus was then determined utilizing a chord modulus IS 516 (1959), which is the slant of two indicated focuses on a pressure strain bend. One point is indicated to be the place the compressive pressure is 40% of the compressive strength, and the other point is at the compressive strain of 5.0×10−5. The determined modulus of elasticity is summed up in Fig: - 12. The outcomes indicated that for M30 concrete, the flexible modulus by and large diminished with an expansion in the RFA substitution proportion.

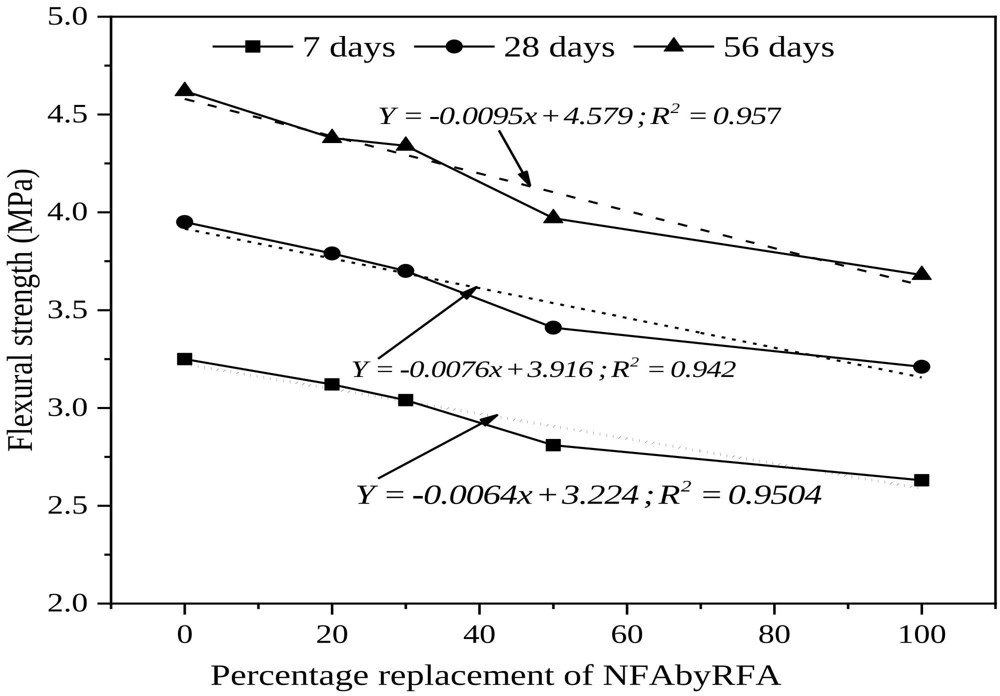

Fig. 10.Variation of flexural strength of concrete prepared by different percentage replacement NFA by RFA

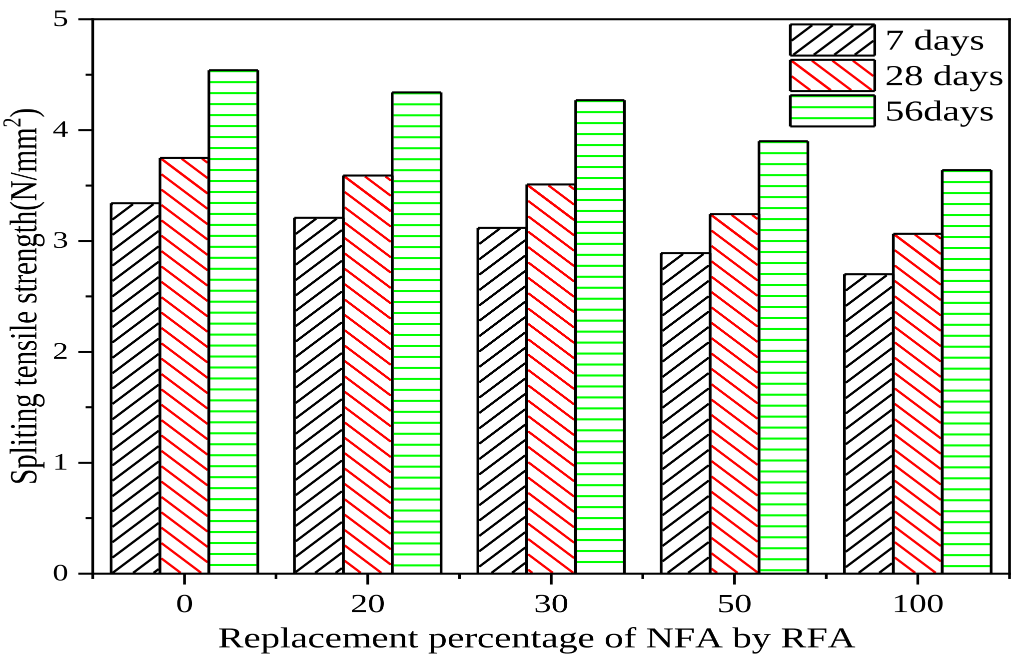

Fig.11.Variation of splitting tensile strength of concrete prepared by different percentage replacement NFA by RFA

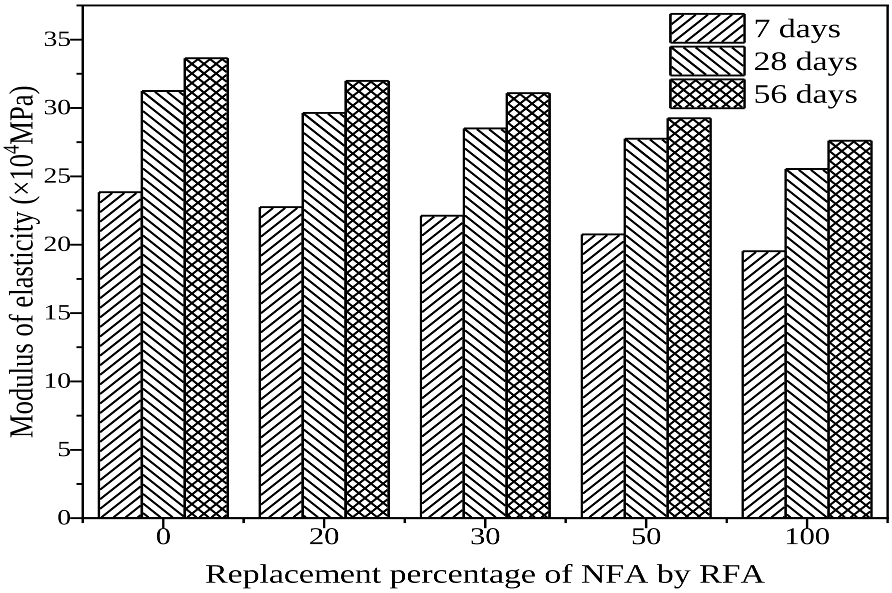

Fig.12. Variation of modulus of elasticity of concrete prepared by different percentage replacement NFA by RFA

4. Conclusions

In this trial experiment a possibility reused of recycled fine aggregates as partially or full replacement of natural fine aggregates in the conventional concrete. Based on experiment results the following conclusions are drawn.

1. Slump value of fresh concrete mix were gradually decreasing with the increasing the replacement percentage of NFA by RFA in conventional concrete. This is due to the adhere mortar attached on surface of RFA.
2. Hardened properties of concrete *i.e*., compressive strength, flexural strength, split tensile strength and modulus of elasticity also decreases as increasing the replacement percentage of NFA by RFA.
3. It is observed from the experimental results the compressive strength, flexural strength, splitting tensile strength and modulus of elasticity reduces 8.63%, 6.32%, 6.25% and 8.75%, respectively in concrete made with 30% replacement of NFA by RFA at 28 days than that of conventional aggregate concrete.
4. While concrete made with 50% replacement of NFA by RFA, the reduction in compressive strength, flexural strength, splitting tensile strength and, modulus of elasticity 13.98% 13.68% 13.52% and 11.16%, respectively at 28 days than that of conventional aggregate concrete.
5. Hardened properties of concrete prepared with 30% percentage NFA by RFAwere found positive effect.

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