RESEARCH ARTICLE

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Experimental Investigation of Recycled Aggregate Concrete Including Metakoline

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Abstract

As construction is increasing day by day in last decade, it is concerned for processing of waste material with the help of recent technology. The current study investigated the effect of metakoline (MK) on mechanical properties of RAC. The current study presents the experimental results of Recycled aggregate (RA) with different percentage 0, 20, 40, 60, 80, 100% in concrete replaced by natural coarse aggregate. Casting of cube, beam, cylinder mould has been done. In addition to this replacement of cement partially with MK also has been introduced. The flexural strength, compressive tensile strength and split tensile strength of M-30 and M-25 have been determined and also there design mix has been prepared. The results show good effect up to 60% aggregate replacement but on further increases the replacement ratio of aggregate, strength decreases. Therefore sustainable concrete may be produced to make environment safe and eco-friendly.

Keywords: Compressive strength, Flexural Strength, Metakoline, Recycled aggregate.

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Introduction

As the demand of concrete as well as cementitous material has increased due to tremendous growth in infrastructure during last few years, the utilization of the waste material is mandatory. Construction and demolish waste is generated about 0.5 billion tons in the world annually 48 million tones in India per annum generated as per the report of Central Pollution Control Board.

In last few year ago tremendous growth in infrastructure going on, so utilization of concrete and cementitious material need with development has increasingly regularly.[1] finding appropriate solutions for reducing the environmental pollutions as a consequence of buildings is important. Using recycled concrete from demolished buildings as an aggregate in new concrete preparation can have a significant role in the sustainable development of the concrete industry; therefore, in this research work, the effect of employing different percentages (i.e., 20, 40, 60, 80 and 100% On the other side, many researcher are working for the improving the quality of concrete and strengthen to improve the life of structure and accomplishment of sustainable development.[2] As the development going on all over the world it give rise urbanization, construction activity and construction waste. Construction and demolish waste worldwide annually generated about 0.5 billion tons[3] Recycled aggregate Concrete (RAC) is new form of concrete that save environment and energy which is eco friendly. [4] Recycled aggregate is made from recycling, crushing in plant, cleaning by mechanical ways, and different grades of recycled aggregate classify,[5] however the surface of recycled aggregate are rough in nature because old mortar are attached with aggregate which gives strength less to the recycled concrete.[6]

As in present day, recycling of aggregate is good way to control the concrete waste as used in building material. Concrete made from recycled aggregate gives higher water absorption and crushing index [4] use of recycled aggregate concrete (RAC) for construction is a globally improvement ensuring infrastructural sustainability. The demand for recycled aggregate concrete is high for development structures due to growing population and changing lifestyle.[7,8]

Furthermore, a significant amount of construction and demolition (C&D) waste produced yearly with the dismantling of the building across all nations in the world, generally C&D waste all over the world produced 3 billion tons every

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year. The main contributor of this waste are only by this major countries like China, India, and USA which give rise roughly two billion tons of construction waste.[8,9] It is already discussed, in the previous studies, that the mechanical properties of the traditional concrete are enhancing when Metakoline (MK) is used in the manufacturing of concrete. The utilization of Metakoline (MK) boost the mechanical properties and improve the durability aspects of conventional aggregate concrete .This is for the reason that of the pozzolanic effect, that produce more of the composite of calcium-silicate-hydrate (C-S-H) that control the strength of both cement paste and concrete.[10,11] traditionally river sand is used as fine aggregate in concrete production. However, due to continuous exploitation of river sand, its availability has become scarce. Construction industry has started using alternate materials as fine aggregate. Out of which manufactured sand is one of the popularly used material as fine aggregate. Materials such as quarry dust and recycled concrete aggregate have issues of dumping and environmental pollution. These materials are viable alternatives for replacement of natural river sand. Recycled concrete, if used as coarse aggregate has problems of water absorption and reduction in strength. Hence, an attempt has been made in this research to use recycled concrete aggregate (RCA).

As we use recycled aggregate (RA) with replacement of natural aggregate ratio of 25, 50, 75, 100% it will reduced the compressive strength of concrete finding appropriate solutions for reducing the environmental pollutions as a consequence of buildings is important. Using recycled concrete from demolished buildings as an aggregate in new concrete preparation can have a significant role in the sustainable development of the concrete industry; therefore, in this research work, the effect of employing different percentages (i.e., 20, 40, 60, 80 and 100%[12] now incorporating of MK in concrete mix it will enhance the strength from 7–8% for 28 days, when 50% aggregate replace with natural aggregate and 6–12 % increase strength when replacement ratio is 100% with mix of MK.[13] the flexural strength of RAC compare to natural aggregate concrete is less, to improve the quality of concrete MK with 10% introduced and value find is about 3.6 to 9%[14] as we further increase the rate of metakoline up to 20% the improvement in flexural strength is less as because of clinker dilution.[15] Now the durability of recycled concrete is less as compare to natural concrete to enhance the durability properties. Carbonation and electrical resistivity of recycled aggregate concrete is poor as compare to natural concrete by adding some amount of metakoline it increase the results and make the concrete more durable.[16]

Experiment and Testing Methods

A .Cement

IS 269:2015 Ordinary Portland cement, OPC 43 grade utilize in concrete mixture with the characteristic strength of 43 Mpa, having specific surface area 2870 the chemical property and physical property is given below in Table 1.[17]

Table 1: Physical property of natural coarse aggregate and recycled coarse aggregate.

Aggregate	*Specific gravity*	*Water absorption*	*Fineness modulus*	*Los abrasion value*
NFA	2.58	0.98	2.78	-
RCA	2.71	6.85	-	26.4
NCA	2.26	0.89	-	14.2

B. Metakoline (MK)

Metakoline procured from the chemical manufacturer in Chennai. 2.49 is the specific gravity of the material. The properties of MK i.e chemical composition given below in Table 2.

C. Natural Fine Aggregate (NFA)

Fine aggregate confirming from Zone -2 as per IS code 383-1979 was used in this research. The fine aggregate is confiscate from near area from Indore. It is passing through 4.75 mm and retained from 2.36 mm sieve was used in this research. The Fineness modulus and specific gravity of the aggregate is 2.79 and 2.76, respectively.

D. Natural Coarse Aggregate (NCA)

Coarse aggregate from near Indore area of size 4.75, 10, 16, 20 mm are taken according to IS 383 -1970. The specific gravity and fineness modulus of coarse aggregate are 2.67 and 6.89, respectively.

E. Recycled Coarse Aggregate (RCA)

Recycled Coarse aggregate collect from Avi Enterprise, Indore (IMC Project) of size 10, 20 mm. The specific gravity of Recycled coarse aggregate are 2.71.[18]

F. Admixture

In this research we utilize SP 430 super plasticizer which is sulfonated naphthalene purchased from Fosroc chemicals India. Dosages are prepared as per the design mix.

Manufacturing and Processing of Samples

The concrete mixture were prepared and mixed in laboratory for 7, 14, 28 days. As the time required mixing the recycled concrete is more as compare to natural aggregate concrete. Total number of 12 mixes was cast in this research project, whose details are shown in Table 3. In this study we design two different mix as per the IS code 10262:2019 guideline. Natural coarse aggregate (NCA) was replaced with recycled coarse aggregate in 20, 40, 60, 80, 100% by weight in laboratory. Cement is replaced by mixing metakoline (MK) 10% by weight. For casting the concrete recycled aggregate firstly soaked in water for 24 hours, after 24 hours it will taken

Table 2: Chemical composition of cement and metakoline

Test	*Loss of ignition*	*Insoluble residue*	*Sulphuric anhydride*	*Magnesia Oxide*	*Lime saturation factor*	*Alumina iron ratio*	*Total chloride*	*Total alkalis*
MK [6]	0.89	-	-	0.24	-	-	-	-
Cement	1.38	2.20	2.33	1.11	0.86	1.07	0.01	0.41

Table 3: Mix designing and proportioning

Mix Designation	*RCA (%)*	*MK (%)*	*NCA (Kg)*	*RCA (Kg)*	*MK (Kg)*	*NFA (Kg)*	*CEMENT (Kg)*	*Water (Kg)*	*Admixture (Kg)*
RM25-0	0	0	1195.09	0	0	616.88	438.13	197.16	-
RM25-20-10	20	10	956.07	239.02	43.81	616.88	394.32	197.16	-
RM25-40-10	40	10	717.05	478.04	43.81	616.88	394.32	197.16	-
RM25-60-10	60	10	478.04	717.05	43.81	616.88	394.32	197.16	-
RM25-80-10	80	10	239.02	956.07	43.81	616.88	394.32	197.16	-
RM25-100-10	100	10	0	1195.1	43.81	616.88	394.32	197.16	-
RM30-0	0	0	1285.75	0	0	658.91	372.4	167.58	4.46
RM30-20-10	20	10	1028.6	257.15	37.24	658.91	335.19	167.58	4.46
RM30-40-10	40	10	771.45	514.3	37.24	658.91	335.19	167.58	4.46
RM30-60-10	60	10	514.3	771.45	37.24	658.91	335.19	167.58	4.46
RM30-80-10	80	10	257.15	1028.6	37.24	658.91	335.19	167.58	4.46
RM30-100-10	100	10	0	1285.8	37.24	658.91	335.19	167.58	4.46

out from water for drying it will place in open air condition, dry saturated condition appears profit of this that water not absorb during mixing of concrete which is utilize for mixing in concrete. As we know compressive strength most important property of concrete in hardened state which is globally recognize by so many codes so the most important effect is considered is bearing effect which short or long term effect of concrete. The hardened concrete also depends upon type and ratio of material used and aggregate shape also considering in this. The cube mould of size 150 x 150 x150 mm is used, size of cylinder is 300 mm height and 150 mm diameter and beam mould size is 150 mm x 150 mm x 700 mm in size. Compressive strength mould 12 number prepare, tensile strength mould 12 number prepare, flexural mould 12 number are prepare.

Different Test Performed

Workability Test

The investigation of workability of all different mix proportions of concrete is done by the slump cone test reference in IS Code 1199-1959 results shows in Table 4.

Compressive Strength

The evaluation of compressive strength of hardened concrete is done by compressive testing machine using by digital hydraulic machine having capacity 2000 Kn. The test is done with specimen of 150 mm in cube. The result is obtained for 7, 14, 28 days code use IS Code 1199-1959 as shown in Figures 1, 2.

Split Tensile Strength

The evaluation of split tensile strength of hardened concrete is done by compressive testing machine using by digital hydraulic machine having capacity 2000 Kn. The test is done with specimen of 150 mm diameter and 300 mm height cylindrical mould. The results are obtained for 7, 14, 28 days code use IS Code 1199-1959 as shown in Figures 3, 4.

Flexural Strength

The investigation of flexural strength was performed as per the guideline of code 516: 1959. The test sample prepare of

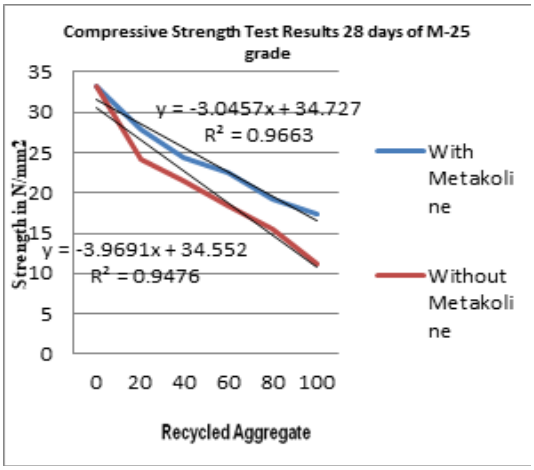

Figure 1: Compressive Strength Results in 28 days of M-25 grade RCA

Table 4: Mix proportions

MIX Proportion	*RA %*	*Compressive Results N/mm²*	*Split Test Results N/mm²*	*Flexural Test Results N/mm²*	*Workability (mm)*
RM25-0	0	33.2	2.37	5.68	92
RM25-20-10	20	31.4	2.22	5.52	91
RM25-40-10	40	28.4	2.12	5.02	91
RM25-60-10	60	26.6	1.97	4.97	89
RM25-80-10	80	23.1	1.86	3.96	85
RM25-100-10	100	18.3	1.26	3.55	70
RM30-0	0	35.2	2.89	5.79	95
RM30-20-10	20	33.1	2.74	5.46	92
RM30-40-10	40	28.2	2.51	4.93	86
RM30-60-10	60	24.5	1.89	4.12	81
RM30-80-10	80	22.3	1.68	3.87	83
RM30-100-10	100	21.02	1.45	3.21	76

Table 5: Statistical modeling results

Measures	*(R^2)*	*MAPE %*	*AA %*	*Observation*
M-25 with MK	0.966	30.04	69.99	6
M-30 with MK	0.954	36.38	63.61	6

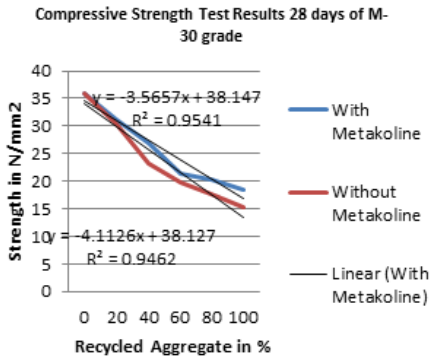

Figure 2: Compressive Strength Results in 28 days of M-30 grade RCA

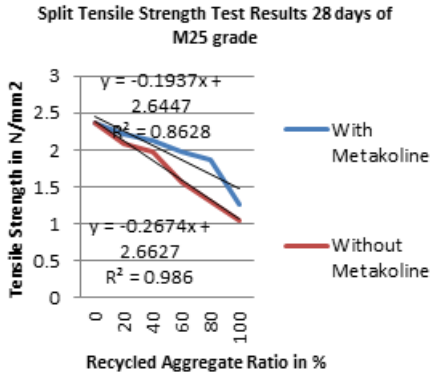

Figure 3: Split Strength Results in 28 days of M-25 grade RCA

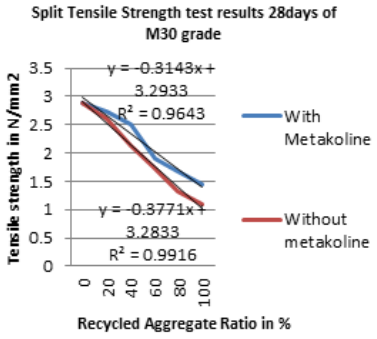

Figure 4: Split Strength Results in 28 days of M-30 grade RCA

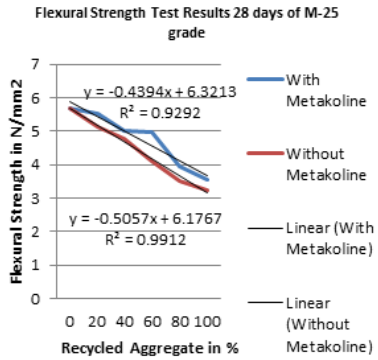

Figure 5: Flexural Strength Results in 28 days of M-25 grade RCA

size 150 x 150 x 700 mm were used to determine strength for each mix proportion 28 days curing, three specimen of each sample prepare results shown in Figures 5, 6.

Result and Discussion

The advantageous effect of using MK in RAC can be easily understood from above results of compressive strength results. As we utilize concrete without mixing of MK, CS

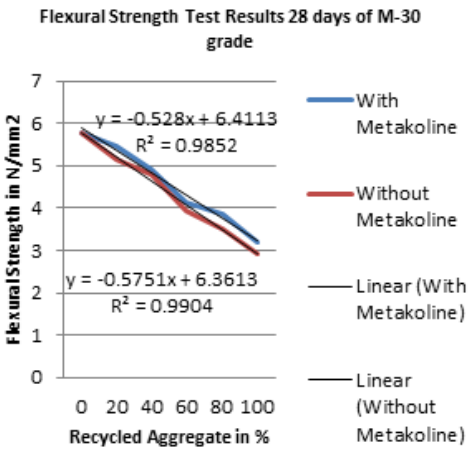

Figure 6: Flexural Strength Results in 28 days of M-30 grade RCA

reduced substantially and introduced of MK in Recycled Aggregate concrete it will increase the bond and increase the quality of concrete. As MK enhance the split strength of RCA from 5–10% and flexural value also increase by 2–8%.

V Statistical Modeling

The correlation between compressive strength and recycled aggregate ratio shown in Table. It shows that concrete with high strength gives lower CS, while at 28 days it possesses good correlation with CS and results shows in Table 5.

To check the correlation model statistical modeling also prepared which shows positive relation. It is observed that the value of R2, MAPE, and AA by MLR modeling gives good results with the actual measurements. The equation of regression is shown below:

$$y = -3.045x + 34.72$$
$$R^2 = 0.966$$
$$y = -3.565x + 38.14$$
$$R^2 = 0.954$$

Conclusion

- The following key finds from above study that is concluded below
- RA has high ability to absorb water, high porosity and rough surface, it will reduce the workability. MK having high surface area at its particle that increases this degradation in the workability which drop up to 50% it is observed.
- Compressive strength, Tensile Strength and Flexural strength reduced if we used only RCA mix concrete. The main reason for this is weakness of the RCA. As we introduced MK in replacement of Cement it will hold the constructive effects.
- Though the utilization of MK in replacement of Cement is 10 % that improve mechanical strength as we further increase the Ratio of Metakoline it does not shows good results.
- The results find in this research helps different researcher to work for sustainability of recycled aggregate concrete mix with MK in construction sector.

However more investigation should be carried out to explore the durability, microstructure behavior of RCA in practical field.

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