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Effect on Compressive Strength and workability of Recycled Coarse Aggregate Concrete Using Metakaolin

Alok Yadav¹, Divyanshu Siddharth², Arjeet Singh³, Anurag Chaudhary⁴, Dr. Tinku Biswas⁵

U.G. Student, Department of Civil Engineering, Galgotias College of Engineering and Technology,
Greater Noida, Uttar Pradesh, India- 201308^{1,2,3,4}

Associate Professor, Department of Civil Engineering, Galgotias College of Engineering and Technology,
Greater Noida, Uttar Pradesh, India- 201308⁵

ABSTRACT: Construction waste has expanded dramatically over the previous years, raising social and environmental concerns about recycling. Because of recent technical breakthroughs, the recycling of leftover concrete has expanded significantly. Landfills are the most common method of storing such garbage. Landfills will generate several environmental problems as a result of improper construction and demolition waste management. NCA will be used indefinitely, resulting in a reserve scarcity. Aggregate recycling could be a viable answer to these concerns. The effects of a mineral addition (Metakaolin) on the reaction of Recycled Aggregate Concrete are compared, as well as the characteristics of conventional and recycled aggregate concrete. The results of experiments using recycled aggregate concrete with differing quantities of mineral additive (Metakaolin) are discussed. Four concrete mixes with 0%, 5%, 10%, 15%, and 20% mineral admixture (Metakaolin) substitutions were cast for attaining compressive strength of 35 N/mm², and another mixture was produced by the use of natural coarse aggregate (NCA) for comparing with other mixtures. In total there are 5 mixes were made. In addition, in all mixtures, recycled aggregate is utilised to completely fill the weight of natural aggregate. After the duration of 28 days, compressive strength and slump tests were evaluated using cube specimens.

KEYWORDS: Metakaolin (MK), Compressive strength, Workability, Recycle coarse aggregate (RCA), Natural coarse aggregate (NCA), Ordinary portland cement (OPC)

I. INTRODUCTION

Due to the economic growth of infrastructure, a huge mass of construction and demolition waste are being created. Landfills are the most common method of storing such garbage. Landfills will generate several environmental problems as a result of improper construction and demolition waste management. NCA will be used indefinitely, resulting in a reserve scarcity. Aggregate recycling could be a viable answer to these concerns [1,2]. And utilise it as fine or coarse aggregates without using natural aggregate. Such a strategy will aid in environmental preservation. Concrete from destroyed concrete structures, for example, may be repurposed as coarse aggregate in concrete manufacturing [3,4]. construction and demolition waste is anticipated to produce 0.5 billion tonnes per year globally [5,6]. However, although construction and demolition waste using in concrete have environmental benefits, its application in concrete is restricted [4,7]. the main reason for not using recycled coarse aggregate in the concrete making because of its poor characteristics in comparison with natural coarse aggregate.

II. RELATED WORK

Mechanical properties of concrete made with the use of recycled coarse aggregate is poorer than that made using natural coarse aggregate. Low strength, high water absorption, high porosity, high shrinkage, and creep characterise recycled coarse aggregate concrete. The amount of the concrete's strength loss is determined by the content of the recycled coarse aggregate. The compressive strength of recycled aggregate concrete is up to 40% lower than that of natural aggregate concrete [1,6,8,9]. The fundamental explanation for such recycled aggregate concrete behaviour is because recycled coarse aggregate tiny pieces have a dissimilar character compositionally. The remaining mortar adhered to the upper surface area of recycled coarse aggregate particles is used to describe them. This connected mortar has a high porosity, low density, and microcracks, all of which contribute to recycled coarse aggregate with a feeble and loose microstructure, lowering recycled aggregate concrete performance. The feeble and loose bond betwixt the recycled coarse aggregate tiny piece and cement slurry is also caused by flaws in the microstructure of the RCA's particles [4]. The poor qualities of a recycled coarse aggregate made scholars think about different methods to conquer this problem of adhered cement on the surface of recycled coarse aggregate. There are several approaches to removing cement from the surface of the recycled coarse aggregate but these approaches were not cost-friendly and durable so scholars have to find some other ways to solve this problem [10, 11] so they use the concept of pozzolanic materials like silica fume, ground blast furnace slag, fly ash, and metakaolin. There are studies that show that these materials can improve compressive strength, and durability (Mechanical property). These qualities improve because of the material's pore-filling quality and pozzolanic behaviour [12].

III. METHODOLOGY

Our Project focuses on studying the effect of the addition of recycled coarse aggregate with metakaolin in the concrete admixture. Recycled concrete aggregate is used as a partial substitute for the conventional coarse aggregate. This project is to find and study the compressive strength and workability (slump test) of the concrete. We have created M35 grade concrete while following the guidelines of Indian standard codes IS:456.

In our study, the ordinary portland cement OPC that we used was grade 53. A table is provided to show the chemical compounds of OPC, as its details are given by the supplier. Metakaolin (MK) what's the mineral admission that we have used to replace the OPC in our studies the chemical and physical properties are shown in the table below that was given by the supplier.

Table 1: Characteristics of Cement and Metakaolin.

Chemical Composition	Cement (%)	Metakaolin (%)
SiO ₂	20.07	54.32
Al ₂ O ₃	5.52	41.31
Fe ₂ O ₃	4.62	4.26
CaO	61.85	0.49
MgO	0.83	0.09
Na ₂ O	0.12	0.13
K ₂ O	0.47	0.51
SO ₃	2.50	0.21
LOI	1.76	0.62
Blaine (m ³ /kg)	361	15000
Specific Gravity	3.16	2.51



Crushing the fragments of destroyed concrete structures that are equivalent in size to our natural aggregate produces the aggregates needed for research. Our recycled coarse aggregate is equivalent in size to natural coarse aggregate. We utilised river sand with a maximum size of 4.7 mm or retained it on a 75-micron filter for fine aggregate.

Mix proportioning: In our project, we have done a study on four types of concrete mixes. All the valuable complete information concerning our mixes is shown in the tables below. The water-cement ratio is (0.39) which is the same for all mixes. The sand we have used is constant for all the mixes having a 777.32 kg/m³ density.

Table 2: Design Mix

Final Design given as below				
Cement	400.2	≈	400	Kg/M ³
20 mm	730.0	≈	730	Kg/M ³
10 mm	469.4	≈	469	Kg/M ³
C.Sand	777.3	≈	777	Kg/M ³
Water	156.1	≈	156	Kg/M ³
Admixture	4.00	≈	4.00	Kg/M ³
Density of Mix	=		2537	Kg/M ³

Table 3: Calculation of Materials

CALCULATION:-				
Dry Volume of Concrete Block			0.00338	cum
Cement			1.350	kg
Aggregate 20mm			2.464	kg
Aggregate 10mm			1.583	kg
Sand			2.622	kg
Water			0.527	kg
Weight of Concrete Block			8.546	kg

Table 4: Mixes Selection and Proportion (Kg/ m³)



The concrete components are mixed in a series of processes, first, the coarse aggregate is placed then the fine aggregate is put over it, and for 2 minutes it was mixed. After that binder cement is added and mixed for another 2 minutes. After mixing all the materials water is added and mixed continuously for another 3 minutes. All the materials were mixed together equally forming a perfect concrete mixture of 17.09 KG. Then we had to check the workability of that concrete and it was ready to cast in 2 different modes.

For the compaction process, we used a compaction rod and it was used 20-25 times on each layer we had taken 4 layers to fill the whole mould. two 150 mm cubes were used to fill all that mixture. When we had finished the casting of the cube was left for 24 hours for curing. On the next day after 24 hours, the cube was removed from the mould and placed on a temperature-controlled water tank and it was kept until the day of testing.

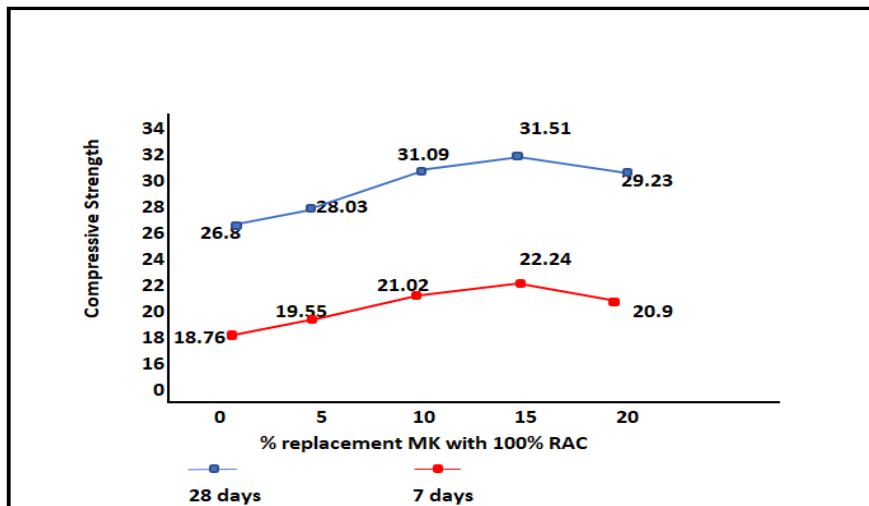


Fig 1: Compressive Strength

IV. EXPERIMENTAL RESULTS

Mix Code	Cement	MK	10mm Agg	20mm Agg	Sand	Water
NMK0	400	0	469	730	777	156
RMK0	400	0	469	730	777	156
RMK05	380	20	469	730	777	156
RMK10	360	40	469	730	777	156
RMK15	340	60	469	730	777	156
RMK20	320	80	469	730	777	156

Compressive strength: The table shows the variance at 7day and also 28day compressive strength to every concrete mixes by fix percentage (100%) of RCA and different percentages of metakaolin. Regardless of curing ages, the figure represents progressive lessen compressive strength because of the amount of RCA increases. The compressive strength on the 7-day of the control concrete mix (R0M0), which contains no RCA or metakaolin is 22.75 N/mm₂ whereas the compressive strength of concrete mixes with 100 percent RCA (R100M0) is 18.78 N/mm₂, indicating a 17.5 % loss in compressive strength. With the progression of the hydration reaction, the strength of concrete mixes begins to increase as the curing ages. However, at all curing ages, the above-described concrete mixes show a similar trend of strength growth.



With the addition of 100 percent RCA to concrete, the compressive strength drops from 35.00N/mm₂ to 26.81 N/mm₂ after 28 days, indicating a 24% loss in strength when compared to the concrete which is made using conventional aggregate.

If we use metakaolin content in percentage as 5.0%, 10.0%, 15.0%, and 20.0% which will be represented as R100M05, R100M10, R100M15, and R100M20 respectively in RACs, the compressive strength of R100M0 improves from 18.78 N/mm₂ to 19.57N/mm₂, 20.99 N/mm₂, 22.23N/mm₂, and 20.89 N/mm₂, respectively. This has a higher strength of 4.20 %, 11.90 %, 18.50 %, and 11.40 % than the conventional concrete. Similarly, the 28-day compressive strength of the given concrete block improves from 26.8N/mm₂ to 28.03 N/mm₂, 31.1 N/mm₂, 31.51N/mm₂, and 29.23N/mm₂, which is 4.6 %, 16%, 17.6%, and 9.1% greater than the control concrete.

Table 5: Experimental Results of Compressive Strength.

Name	Compressive strength (N/mm ²)	
	7 day	28day
Mk0	18.768	26.8
MK5	19.55	28.03
MK10	21.02	31.09
MK15	22.24	31.51
MK20	20.9	29.23

Workability: Table 4 shows the result value of a workability (slump) test done for determining the workability and slump value of freshly made concrete containing various percentages of metakaolin with a fixed amount of RCA (100%). The slump value of the controlled environment natural concrete mix is 120mm, but it reduces by 20mm when we add 100 percent RCA which gives a slump value of 100mm.

Table 6: Experimental Results of Slump Value

Name	Slump Values (mm)
NMK0	120
RMK0	100
RMK5	95
RMK10	90
RMK15	80
RMK20	75

The addition of metakaolin reduces the slump and is not being affected by any replaced value of NCA to RCA. The values of slumps for conventional concrete mixtures containing 5.0%, 10.0%, 15.0%, and 20.0% metakaolin are 74.0mm, 72.0mm, 71.8mm, and 70.0mm sequentially. For the above metakaolin replacement percentages, the value of slumps for RAC mixtures with 100 percent RCA are 95.0mm, 90.1mm, 80mm, and 75mm, respectively.

V. CONCLUSION

Coarse recycled aggregate affects concrete workability due to its strong water absorption capability, rugged total surface, and more porosity than normal aggregate (coarse). Because of the high surface area of the material particles, metakaolin had worsened the RAC's workability depression. Workability was shown to be reduced by up to 50%.

When RCA is employed, compressive strengths decrease. Compressive strength decreased by roughly 24% in each case. The RCA's flaws are the primary cause of this behaviour.

- The use of MK instead of cement has a positive impact on strength. The pozzolanic reaction of MK particles is the main explanation.

- When MK is used in place of up to 20% of the cement weight, comparable compressive strength (compressive) can be achieved.

For all curing ages, increasing the amount of RCA in concrete diminishes the compressive strength. The compressive strength is gone down by 20% because of the poor characteristic of RCA compared with the NCA's characteristic. However, it was discovered that adding metakaolin to the mix compensated for the RAC's compressive strength loss by increasing 28-day strength by up to 17.6% at a 15% metakaolin replacement level. The pozzolanic and filling effect of tiny metakaolin particles is responsible for the increased strength.

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