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Experimental Study on Mechanical Properties of Concrete Containing Metakaolin and Red Mud as Partial Replacement of Cement

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Abstract - *In this time waste material negatively affects in environment. If we leave waste material directly to the environment, it might cause serious environmental issues. These waste materials can be utilized to produce new products so that natural resources can be used more efficiently. The aim of this present research work is to investigate the possibility of partial replacing of Metakaolin and Red mud as cement in the concrete. Metakaolin and Red mud will be replaced up to 5%, 10%, 15%, 20% and 15% respectively by weight of cement. Combination doing check for compressive strength, flexural strength and Durability Test by using M40, M50 and M60 grade of concrete at 28, 56 and 90 days. Metakaolin was a pozzolanic material used in wide range in partial replacement of cement in concrete which was treated as pozzolanic action. Red mud is a waste material generated by the Bayer Process widely used to produce alumina from bauxite throughout the world. In this two materials replacement Experimental Study On the Mechanical and durability Properties of Concrete.*

Key Words: Metakaolin, Red Mud, Compressive Test, Flexure Test, Durability Test.

1. INTRODUCTION

Concrete is literally the material that forms the basis of modem history. More than 15 billion tons of concrete are created each year, which is measured to be most significant building material. among world population increasing, concrete demand is estimated to raise to about 20 billion tons per year by 2050. In present society, new roads , high-rise buildings and concrete that are enthralled by buildings are completely very important. Concrete is the only building material actually made on site using locally accessible materials and has a unique distinction that can be cast to any shape and size desired. Over the past decade, aluminum production has risen by about 1% despite the congestion and certain time span. However, cement production results in significant amounts of carbon dioxide and greenhouse gas emissions. 1 ton of Portland cement clinker yields 1 ton of carbon dioxide and other greenhouse gases. To reduce carbon dioxide emissions associated with cement production, Portland cement needs to be reduced by reducing cement usage. Therefore, the CO2 emissions associated with the manufacture of Portland cement need to find alternative types of substances that can be significantly reduced by reducing the production of clinker at present.

1.1 Metakaolin

Metakaolin is pozzolan, almost certainly the majority effective pozzolanic material for utilize in concrete. It is a manufactured goods that is artificial for use quite than a by-product and is formed when china clay, the mineral kaolin, is heated to a temperature between 600 and 800ºC. When used to change cement at replaced of 5 to 10% by weight, concrete created is usually supplementary cohesive and less likely to bleed. since a product pumping and finishing process require a smaller amount attempt.

Table -1: Chemical Composition of Metakaolin

Chemical Composition of Metakaolin		
Sr No:	Chemical Composition	Weight(%)
1.)	$Sio_2+Al_2O_3+Fe_2O_3$	96.88%
2.)	Cao	0.39%
3.)	Mgo	0.08%
4.)	Tio_2	1.35%
5.)	Na_2O	0.56%
6.)	K_2O	0.06%
7.)	Li_2O	Nil.
8.)	L.O.I	0.68%

1.2 Red mud

Red clay is rich in iron-rich residue of bauxite. It is one of the major by-products of Bayer's alumina manufacture process. Generally, about 2 to 4 tons of bauxite are produced and about 1 tone is produced, which is required for the manufacture of each ton of alumina Al2O3. Red clay consists of a mixture of solid and metal oxide impurities, and one of the current aluminum industries now has the most important disposal problem. Red mud color is caused by oxidized iron, which can account for 60% of the accumulation of red mud. Other leading particles in addition

to iron include silica, unbleached remaining aluminum and titanium oxide. Red mud cannot be handled easily. As a waste in the Bayer process, mud is very basic with a pH between 10 & 13.

Table -2: Chemical Composition of Red Mud

Chemical Composition of Red Mud		
Sr No:	Chemical Composition	Weight(%)
1.)	Al_2O_3	20.22
2.)	SiO_2	12-15
3.)	Fe_2O_3	40-45
4.)	TiO_2	1.8-2.0
5.)	CaO_2	1.0-2.0
6.)	Na_2O	4.0-5.0

2. Methodology

2.1 Compressive Strength Test

For the cube compression test the moulds of size having 150x150x150mm are using for test. . A tamping rod of steel bar having 16 mm diameter and 60 cm long and bullet pointed at end should be using for compaction. The concrete is filled in the mould in approximate 3 layers of having each layer size 5cm approximately. The concrete distribution should be evenly either by mechanical vibrator or through hand tamping. every layer of the concrete be supposed to be compacted well and the compaction must not be a smaller amount than 35 strokes per layer using tamping rod. Then after the leveling of top surface should be done and make the surface smooth by using trowel. Then test specimens are uninvolved as of the moulds after 24h. However, in Geo-polymer concrete water curing is not needed. Curing is carried out at room temperature. After the certain curing period, top surface is cleared when, it is considered for testing. The compressive strength can be calculated as the following formula.

Compressive Strength (MPa) = (Failure load) / (C/S area of cube specimen).

2.2 Flexural Strength Test

The strength of mind of tensile strength through flexural test is the ideal method because of its similarity to the actual life situation that are faced by flexural members. The normal size of beam specimen is 150x150x750mm. The beam failure occur in bending when acting stress on bottom surface of the beam exceed the limit and it is term because modulus of rupture. In this type of test, loads are applied equally at the distance of $1/3^{rd}$ part from the both supports of the testing specimen. Therefore, it has the same reaction at both of the supports. Under such type of loading, beam is subjected to pure bending at the $1/3^{rd}$ portion of centre of beam.
The flexural strength of beam for this can be calculated as the following formula.

$$\text{Flexural strength (MPa)} = (P \times L) / (b \times d^2)$$

Where,
P = Failure load,
L = Centre to Centre distance between the support,
b = width of specimen,
d = depth of specimen at point of failure.

2.3 Durability Test

Concrete cube of size 150x150x150 mm are prepared for various percentages of Metakaolin & Red mud addition. After that the Specimen are casted and curing in mould. After 24 hour all the specimens are demoulded and kept in tank for 7 days curing. After 7 day all specimen are kept in atmosphere for 2 days for constant weight, subsequently, the specimens are weighed and immersed in 5% hydrochloric acid (HCL), sulphuric acid (H_2SO_4), sodium sulphate (Na_2SO_4) in different tank solution for 91 days. After 91 days of immersing, the specimens are taken out and washed in running water and kept in atmosphere for 2 days. Also check the change in compressive strength.

3. Design Mix Methodology

In the methodology carried out the concrete mix design for M40, M50 and M60 grade of concrete using IS 10262:22019.

- Data of Mix Design For M-40 Grade Of Concrete As Per IS 10262:2019 is shown in table-3.
- Data of Mix Design For M-50 Grade Of Concrete As Per IS 10262:2019 is shown in table-4.
- Data of Mix Design For M-60 Grade Of Concrete As Per IS 10262:2019 is shown in table-5.

Table -3: Mix Design For M-40 Grade Of Concrete

Mix Design For M-40 Grade Of Concrete			
Sr No:	Material	Quantity	Mix Ratio
1.)	Cement	361 kg/m^3	1
2.)	Water	155 kg/m^3	0.43
3.)	Fine aggregate	713 kg/m^3	1.97
4.)	Coarse aggregate	1125 kg/m^3	3.12

5.)	Admixture	3.61 kg/m³	1%

Table -4: Mix Design For M-50 Grade Of Concrete

Mix Design For M-50 Grade Of Concrete			
Sr No:	Material	Quantity	Mix Ratio
1.)	Cement	420 kg/m³	1
2.)	Water	155 kg/m³	0.37
3.)	Fine aggregate	693 kg/m³	1.65
4.)	Coarse aggregate	1092 kg/m³	2.6
5.)	Admixture	4.2 kg/m³	1%

Table -5: Mix Design For M-60 Grade Of Concrete

Mix Design For M-60 Grade Of Concrete			
Sr No:	Material	Quantity	Mix Ratio
1.)	Cement	470 kg/m³	1
2.)	Water	155 kg/m³	0.33
3.)	Fine aggregate	675 kg/m³	1.43
4.)	Coarse aggregate	1065 kg/m³	2.26
5.)	Admixture	4.7 kg/m³	1%

4. Experimental study

4.1 General

For compressive strength test, cube specimens 150x150x150 mm were casted for M40, M50 and M60 grade of concrete. For flexural strength test, beam specimens of dimension 150x150x750mm are casted for M40, M50 and M60 grade of concrete.

4.2 Casting and Test procedure

Prepare Materials

Marking in Cubes and Beams				
Sr No:	Percentages	M40	M50	M60
1.)	(0%M.K & 0%R.M)	400	500	600
2.)	(5%M.K & 15%R.M)	405	505	605
3.)	(10%M.K & 15%R.M)	410	510	610
4.)	(15%M.K & 15%R.M)	415	515	615
5.)	(20%M.K & 15%R.M)	420	520	620

Casting cube

After Curing

Compressive Test

Flexural Test

Durability Test

5. Result

5.1 Compressive strength Test and Flexure Strength Test

A. Compressive strength and flexure strength for M40 grade concrete.

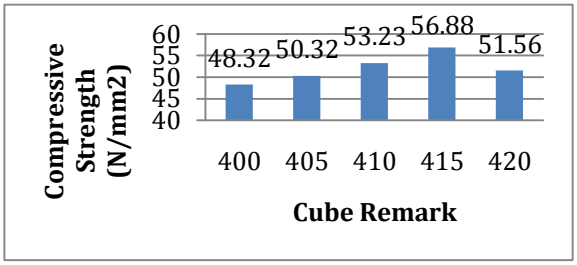

Chart -1: Compressive strength for M40 concrete grade.

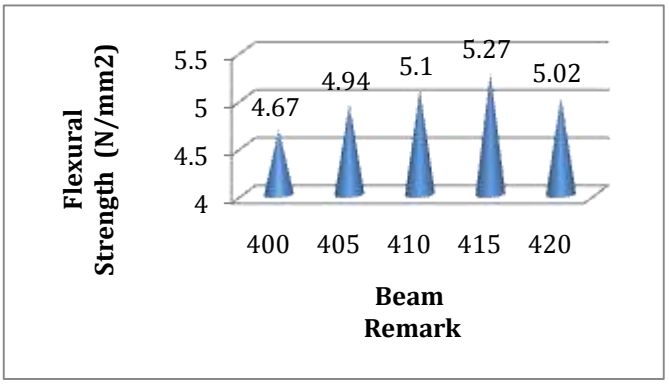

Chart -1: Flexural strength for M40 concrete grade.

B. Compressive strength and flexure strength for M50 grade concrete.

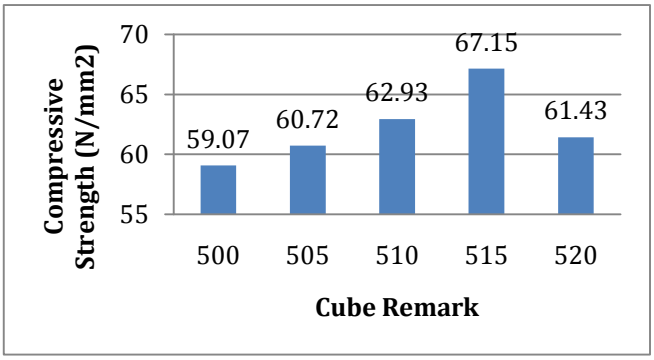

Chart -1: Compressive strength for M50 concrete grade.

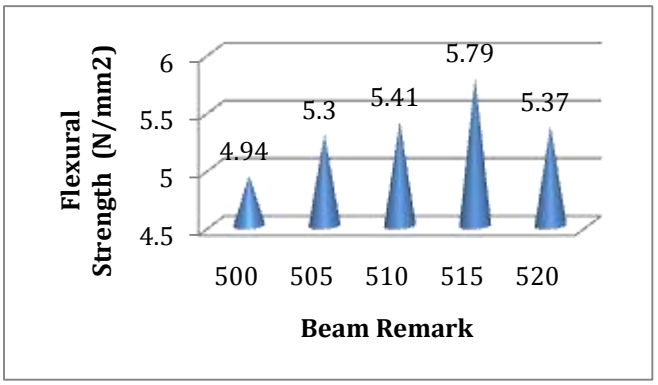

Chart -1: Flexural strength for 50 concrete grade.

C. Compressive strength and flexure strength for M60 grade concrete.

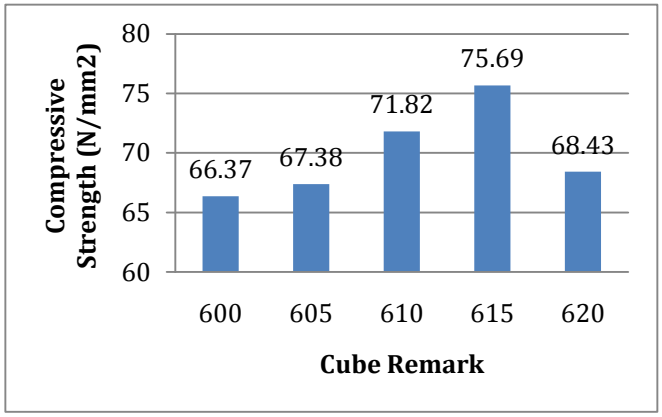

Chart -1: Compressive strength for M50 concrete grade.

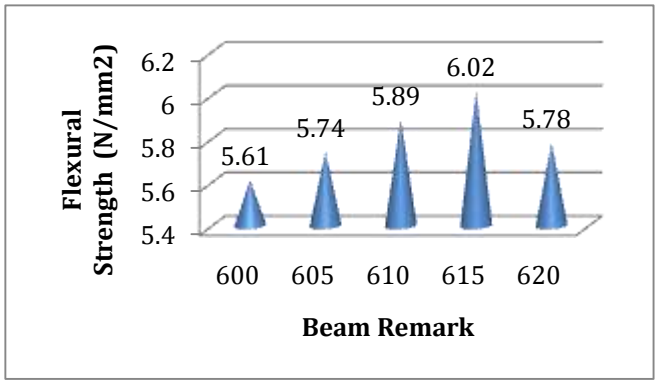

Chart -1: Flexural strength for M40 concrete grade.

5.2 Durability Test Result

A. Compressive strength for M40 grade concrete.

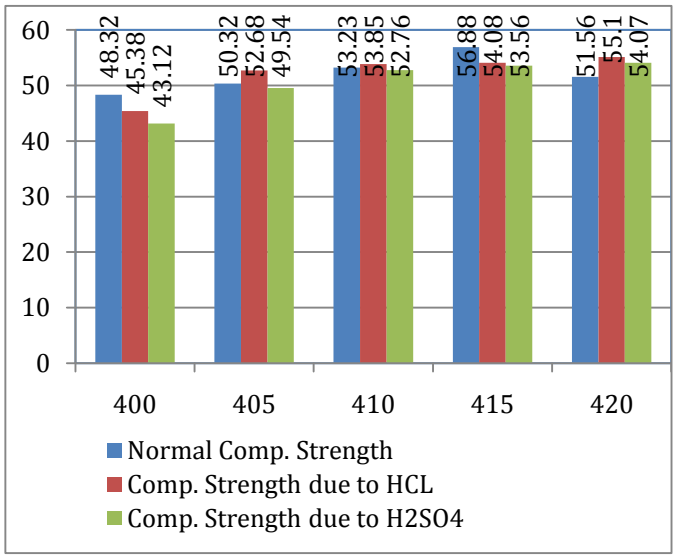

Chart -1: Compressive strength of M40 grade cubes after performing durability test in acid attack.

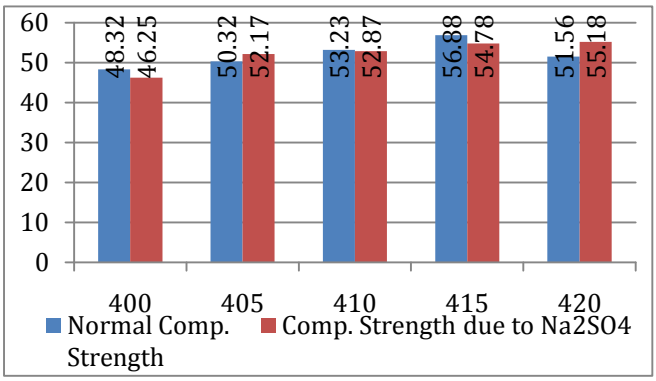

Chart -1: Compressive strength of M40 grade cubes after performing durability test in sulphate attack.

B. Compressive strength for M50 grade concrete.

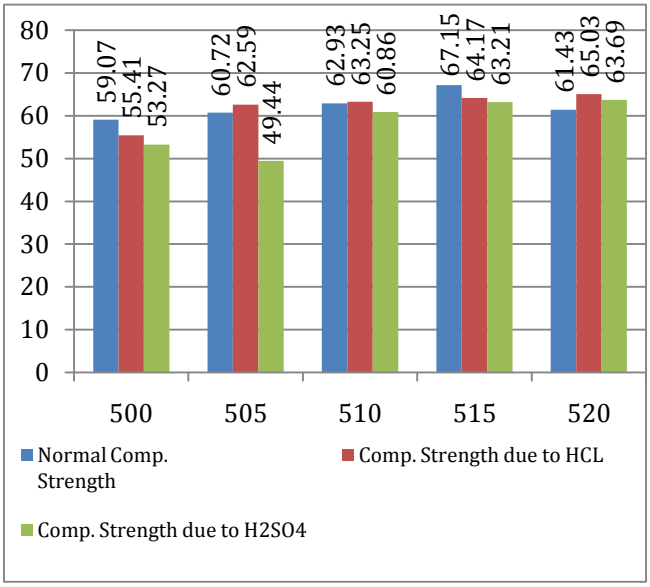

Chart -1: Compressive strength of M50 grade cubes after performing durability test in acid attack.

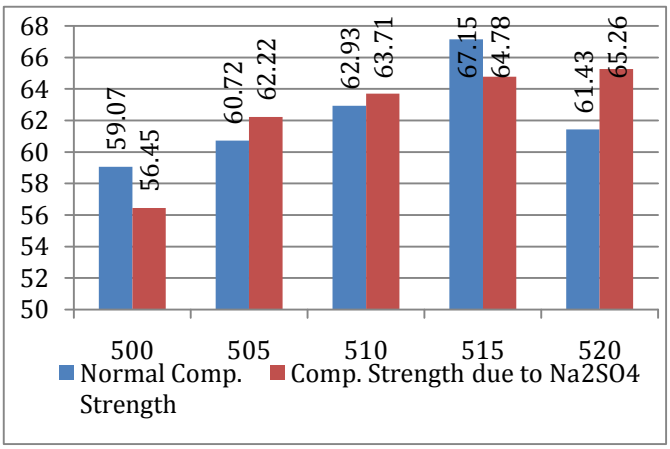

Chart -1: Compressive strength of M50 grade cubes after performing durability test in acid attack.

C. Compressive strength for M60 grade concrete.

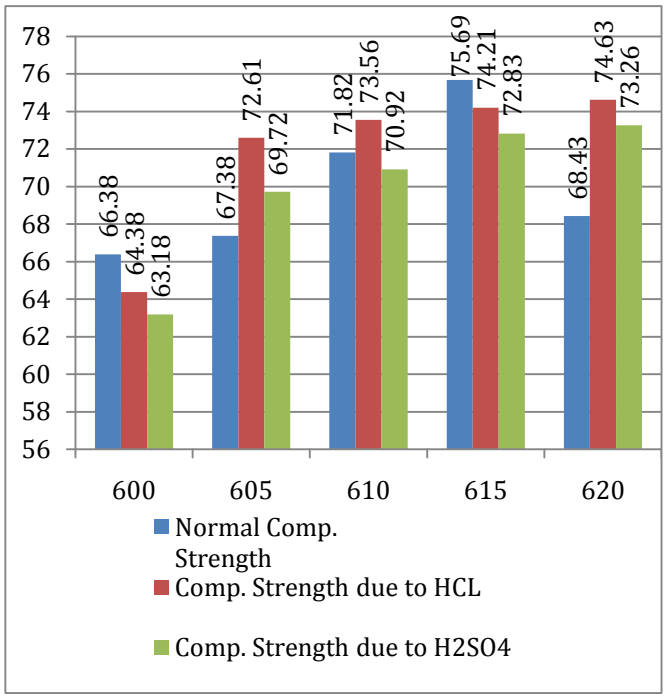

Chart -1: Compressive strength of M60 grade cubes after performing durability test in acid attack.

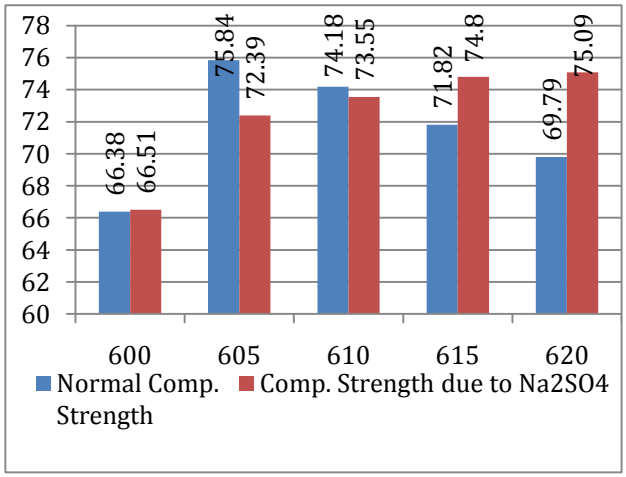

Chart -1: Compressive strength of M60 grade cubes after performing durability test in sulphate attack.

6. CONCLUSIONS

1) The observation in this study is the beneficial effect of using different pozzolanic materials in concrete the same as a limited replacement of Portland cement not only with regards to concrete engineering properties and durability enhancement but also for environmental considerations and reduction of the ECO2 of concrete.
2) The environmental cost (impact) was examined in terms of embodied CO2 with regard to pozzolans

added. This indicate so as to environmental profit MK-based concretes as compared to PC concretes.

3) By embed even little amount of MK in concrete manufacture, the concrete industry tend to move surely towards a extra cleaner production and significantly contribute to decrease the environmental charge connected to that sector.
4) That red mud on individual replace with cement improve its mechanical properties and proves to subsist economical. Red mud can be efficiently using as replacement material for cement and substitute enable the great utilization of waste product.
5) Red mud did not produce of the cement properties, rather enhanced the cement quality by way dropping the setting time & better compressive strength.
6) Increasing compressive strength in Metakaolin up to 15% replacement of Cement and after falling compressive strength.
7) At 15% Metakaolin replacement of cement is 20% increasing compressive strength.
8) And 15% of Red mud replacement of cement in concrete increasing 10% of compressive strength.
9) Until the result obtained high Compressive strength of M40, M50 and M60 grade of concrete is achieved 20%, 16% and 13% increment respectively at 15% replacement with Metakaolin & at 15% replacement with Red mud.
10) For Flexure strength of M40, M50 and M60 grade of concrete is achieved 9%, 8% and 7.5% increment respectively at 15% replacement with Metakaolin & at 15% replacement with Red mud.
11) In the durability test, the compression strength of concrete increasing compared to the normal M40, M50 and M60 grade of concrete at 20% replacement with Metakaolin & at 15% replacement with Red mud. From the durability results, it is observed that the strength due to H_2SO_4 is lesser than the strength due to HCL and Na_2SO_4.

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