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EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF CONCRETE WITH PARTIAL REPLACEMENT OF COPPER SLAG AS FINE AGGREGATE AND ZEOLITE AS CEMENT

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Abstract - Currently the CO2 concentration in the environment is getting increased leading to serious climate change and green house effect. A large amount of by-product or wastes such as fly-ash, zeolite, GGBS, silica fume, copper slag etc. are generated by industries, which causes environmental as well as health problems due to dumping and disposal. Study has been carried out to explore the possibility of using zeolite and copper slag as a partial replacement of Cement and Fine Aggregate respectively in concrete. In this dissertation concrete is casted for M30, M40 and M50 grade and the partial replacement of concrete materials were decided to re-use industrial waste such as copper slag is replacement by weight of sand and the zeolite as replacement by weight of cement. The cubes and cylinder were casted and tested for compression and Split tension strength at 28 days curing of concrete and durability at 56 days of curing of concrete.

Key Words*: *Concrete, Zeolite, Copper slag, Partial replacement, Cement, Fine aggregate, compression Split tension, Strength.

1. INTRODUCTION

Concrete is described by the type of concrete or cement used, as well as the characteristics it exhibits and the methods used to make it. The persona of ordinary structural concrete is essentially determined by the water-to-cement ratio. All other factors being equal, the lower the water content, the heavier the concrete. The mixture must have only enough water to ensure that each molecule of the mixture is properly coated in cement paste, that the spaces between the mixtures are filled, and that the concrete is liquid enough to be poured and unfold effectively. The volume of cement in comparison to the mixture (expressed as a three-part ratio—cement to fine mixture to coarse aggregate) is another factor that affects longevity. Where extra strength is needed, there would be significantly less aggregate. The force used to compress a sample of a given age or hardness is measured in kilos per square inch or kilogram's per rectangular centimeter of strength. Environmental conditions, including temperature and moisture, have an impact on the strength of concrete. It will undergo unequal tensile stresses if it is allowed to dry too quickly, which cannot be resisted in an imperfectly hardened kingdom. Curing is the process of keeping concrete wet for a period of time after it has been poured in order to slow the shrinkage that occurs as it hardens. Low temperatures have a negative impact on its strength. To compensate for this, a calcium chloride addition is added into the cement. Curing is the process of keeping concrete wet for a period of time after it has been poured in order to slow the shrinkage that occurs as it hardens. Low temperatures have a negative impact on its strength. To compensate for this, a calcium chloride addition is added into the cement.

Table 1.1 Chemical Properties of Zeolite and Copper slag

Binder	**Zeolite(%)**	**Copper slag(%)**
pH value	8.79	—
Colour	White	—
CaO	2.77%	—
SiO_2	62.09%	58.00%
Al_2O_3	10.36%	0.57%
Fe_2O_3	0.95%	33.4%
MgO	0.80%	—
K_2O	1.75%	0.018%
SO_3	0.195%	—
Na_2O	0.89%	0.108%
Cuo	—	0.20%
Loss on Ignition	—	0.08%

Table 2.2 Physical Properties of Zeolite and Copper slag

Binder	Zeolite(%)	Copper slag(%)
Physical Appearance & Colour	Ivory colour Fine Powder	—
Water Absorption, %	1.7	0.10
Specific Gravity	2.68	3.24
Bulk Density (g/cc)	1.57	1.68
Moisture content, %	—	0.08

2. BACKGROUND LITERATURE

According to previous study of **:** M.A.G. dos Anjos, A.T.C. Sales, N. Andrade The study examines the feasibility of using blasted copper slag, which is formed during abrasive blasting, in concrete, where the copper slag is substituted by fine aggregate. High aggregate substitution ratios of 0 %, 20%, 40%, 60%, 80%, and 100 % were used to create concrete mixtures. For the compression strength test and gives batter results at 40% of copper slag [1].

According to K.Prasanth and t. Naresh kumar Make the fresh concrete by replacing of cement by zeolite in different percentage, such as 0%, 10%, 20%, 30% & 40%. (for M30 grade of concrete). The compressive strength is maximum at 10% and 20% replacement of cement with zeolite [2]. According to Vusa Maheshbabu, B. Anjana Devi, Bopparaju Maheshbabu when use the zeolite in partial replacement of cements it increase the strength of the cubes as well as reduce the pollution of the environmental. In this study GGBS used at 5%, 10%, 15%, 20% for M20 grades. It is gives increase strength values at 10% compare to usual mixes [3].

According to Swetapadma Panda, Pradip Sarkar and Robin Davis For the design mix, three different water-cement ratios were used, with copper slag as the fine aggregate. from IS 456-2000, the maximum water-cement ratio of M40 grade concrete is 0.45. As a result, three water-cement ratios were used in the current study: 0.55, 0.45, and 0.35 in a decreasing order for the various exposure conditions as per IS 10262-2000. Various percentages of copper slag were considered, including 0%, 20%, 40%, 60%, and 80%. Compressive strength rises as the amount of copper slag in the mix rises, and it's inversely proportional to water-cement ratios. The compressive strength of copper slag blended concrete reduces as the water-cement ratio rises [4].

According to Sreelakshmi S, Sruthi KP, Mohammed Munavvir P, Mashad V Due to depletion of natural river sand deposits and environmental restrictions, concrete manufacturers are looking for suitable replacement fine aggregate. One such alternative is "Manufactured sand (M sand)." For the built concrete of M25 standard, copper slag is partially replaced with M sand and natural sand. The highest compressive strength is achieved when 40 percent copper slag is replaced, with a 40 % increment [5].

According to Mr. Suhas S. Malkhare, Prof. Atul B. Pujari

For M25 concrete with a water cement ratio of 0.50, mix proportions must be calculated. Copper slag is used to replace the fine aggregate in the following proportions: 0%, 20%, 30%, 40%, 50%, 60%, 80%, and 100%. The optimum percentage copper slag was achieved at 40% replacement of sand by copper slag, according to the test results [6].

According to Sumathy Raju, Brindha Dharmar The M30 concrete grade was created with a constant water–cement ratio of 0.4. Fly ash is used to partly replace cement from 0 to 30% with a 10% increment, and Copper slag is used to replace natural sand from 0% to 100% with a 20% increment. The concrete's compressive strength was checked after 3, 7, 14, 28, 56, and 90 days of curing. In comparison to control concrete specimens, the addition of 40% copper slag as fine aggregate increases the mechanical strength of the resulting concrete [7]. According to Nalleni Sreeharsha, K.V.Ramana research is conducted in two stages, with the first phase consisting of an M35 grade concrete mix with partial replacement of cement by 0%, 10%, 15%, 20%, and 25% zeolite to determine the optimum percentage of replacement at which maximum compressive and tensile strength is reached. It is observed that when cement is partially replaced with 15% of zeolite concrete maximum strength is achieved [8].

According to Yugasini.S1, Umamaguesvari.M, Muthaiyan.P, Suman.S The procedure is performed in two steps in an initial mix of M30 Grade Concrete, with partial replacement of cement to Zeolite of 0%, 10%, 20%, 30%, and tests are used to find the optimum replacement percentage and also obtain the concrete's strength characteristics. For find the optimum strength, the second mix of M30 Grade Concrete uses an amalgam of Zeolite and GGBS to be partly substituted with cement by a 20% composition of Zeolite constant with 5%, 10%, and 15% of GGBS [9].

3. Material

3.1 Cement

The cement used in this project is an ordinary Portland cement 53 grade manufacturing by Hathi Cement Company. The Specific gravity of cement is 3.15.

3.2 Fine Aggregate

Fine aggregate passing through 4.75 mm IS sieve conforming to grading zone II of IS 383:1970 and having a specific gravity of 2.66 was used in this work.

3.3 Coarse Aggregate

Coarse aggregate available from local sources with a size of 10mm and 20 mm having a specific gravity is respectively 2.98 and 2.85 and also conforming to IS 2386:1963 was used as coarse aggregate in this study.

3.4 Zeolite

Zeolite is a type of porous volcanic tuff that includes hydrated crystalline aluminosilicate minerals that are alkaline when combined with earth-alkaline metals. Specific gravity and water absorption is 2.68 and 1.7 respectively.

3.5 Copper slag

Copper slag is a by-product of the copper refining process. If the copper settles into the smelter, its density increases, impurities remain in the surface layer, and it is then transferred to a water basin with a low temperature for solidification. Specific Gravity and water absorption is 3.24 and 0.10 respectively.

3.6 Water

The water needs to be clean and contained in order to avoid side effects that could degrade the concrete or interfere with the hydration process.

4. Experimental Study

4.1 Mix design

Table 4.1: Mix Proportion for 1m^3

Concrete Grade	Water	Cement	Fine Agg.	Coarse Agg.
M30	197 litre	469kg	668.02 kg	1148.16kg
M40	197 litre	492.5kg	653.98 kg	1143.25kg

4.2 Casting schedule

Mix	Z	CS	Compressive Strength In(Days)		Split-Tensile (days)	Durability (days)
			7	28	28	56
M1	0	0	3	3	3	6
M2	10	0	3	3	3	6
M3	15	0	3	3	3	6
M4	20	0	3	3	3	6
M5	10	20	3	3	3	6
M6	15	20	3	3	3	6
M7	20	20	3	3	3	6
M8	10	30	3	3	3	6
M9	15	30	3	3	3	6
M10	20	30	3	3	3	6
M11	10	40	3	3	3	6
M12	15	40	3	3	3	6
M13	20	40	3	3	3	6
			39	39	39	78

5. Test Result and Discussion

5.1 Slump Test

Slump values with various proportions of Zeolite and Copper slag replacing cement and fine aggregate respectively in M30 and M40 grade concrete were shown in the table 5.1.

Table 5.1: Slump values with various proportions of Zeolite and Copper slag.

Mix Type	Zeolite (%)	Copper slag (%)	M30 (mm)	M40 (mm)
M1	0	0	58	55
M2	10	0	61	57
M3	15	0	62	61
M4	20	0	65	64
M5	10	20	64	62
M6	15	20	66	65
M7	20	20	70	68
M8	10	30	65	66
M9	15	30	68	64
M10	20	30	70	67
M11	10	40	66	65
M12	15	40	68	65
M13	20	40	74	70

5.2 Compressive Strength Test

A cube specimen was cast to find out the compressive strength of the concrete. Compressive strength of concrete mixtures made with Zeolite and Copper slag was determined 7 and 28 days of curing. The average of three samples was taken for every testing age. The test results for compressive strength are presented in table 5.2.

Table 5.2: Compressive Strength for M30 grade Concrete at 7 and 28 days

Mix Type	Zeolite (%)	Copper slag (%)	7 Days (N/mm²)	28 days (N/mm²)
M1	0	0	21.45	37.96
M2	10	0	22.84	39.22
M3	15	0	20.77	41.36
M4	20	0	21.49	39.83
M5	10	20	23.29	40.07
M6	15	20	22.74	42.84
M7	20	20	22.59	40.33
M8	10	30	24.98	42.75
M9	15	30	24.84	44.06
M10	20	30	23.92	42.67
M11	10	40	25.62	43.19
M12	15	40	24.49	43.85
M13	20	40	22.57	40.13

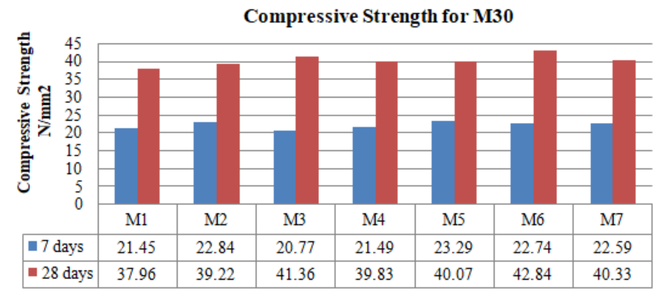

Figure 5.1: Compressive Strength for M30

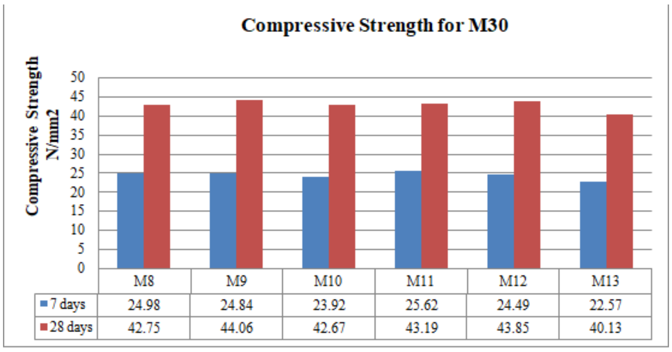

Figure 5.2: Compressive Strength for M30

Table 5.3: Compressive Strength for M40 grade Concrete at 7 and 28 days

Mix Type	Zeolite (%)	Copper slag (%)	7 Days (N/mm²)	28 days (N/mm²)
M1	0	0	28.52	48.76
M2	10	0	29.88	51.81
M3	15	0	31.70	50.23
M4	20	0	29.24	49.66
M5	10	20	30.39	52.18
M6	15	20	31.67	52.37
M7	20	20	31.13	51.29
M8	10	30	33.47	54.94
M9	15	30	32.22	55.61
M10	20	30	30.16	52.02
M11	10	40	32.99	51.26
M12	15	40	32.58	53.74
M13	20	40	31.91	49.95

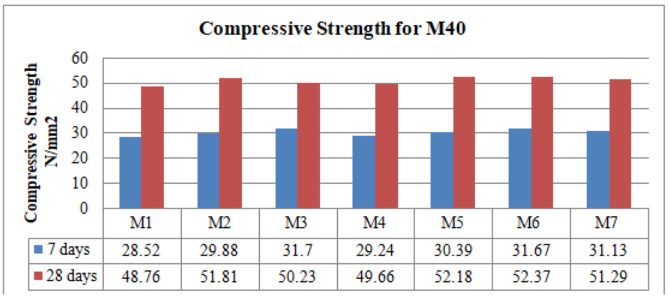

Figure 5.3: Compressive Strength for M40

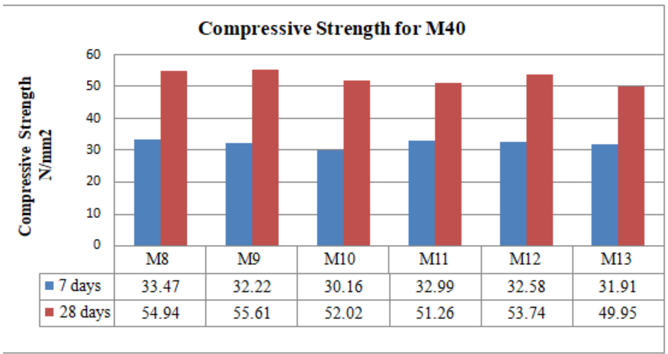

Figure 5.4: Compressive Strength for M40

5.4 Split Tensile Strength Test

A cylindrical specimen was cast to find out the split tensile strength of the concrete and the average of three cylinders for each mix was tested. Split tensile strength of concrete specimens made with Zeolite and copper slag was determined at 28 days of curing.

Table 5.4: Split Tensile Strength for M30 and M40 grade Concrete at 28 days

Mix Type	Zeolite (%)	Copper slag (%)	M30 (mm)	M40 (mm)
M1	0	0	3.86	4.30
M2	10	0	3.97	4.42
M3	15	0	4.15	4.47
M4	20	0	4.07	4.45
M5	10	20	4.22	4.55
M6	15	20	4.38	4.63
M7	20	20	4.25	4.52
M8	10	30	4.36	4.71

M9	15	30	4.40	4.74
M10	20	30	4.32	4.67
M11	10	40	4.46	4.88
M12	15	40	4.51	4.83
M13	20	40	4.34	4.59

5.5 Durability Test

The concrete cubes were cast and cured for a period of 28 days. After 28 days curing of specimens, cube surfaces were cleaned and weighed. The specimens were immersed in hydrochloric acid and sodium sulphate solution for acid attack and sulphate attack. The solution was checked periodically. After the 28 days, the specimens were removed from the solution. Percentage weight loss was determined and percentage of strength loss determined. To conduct this test, 5% by volume of hydrochloric acid and sodium sulphate was mixed with ordinary potable water.

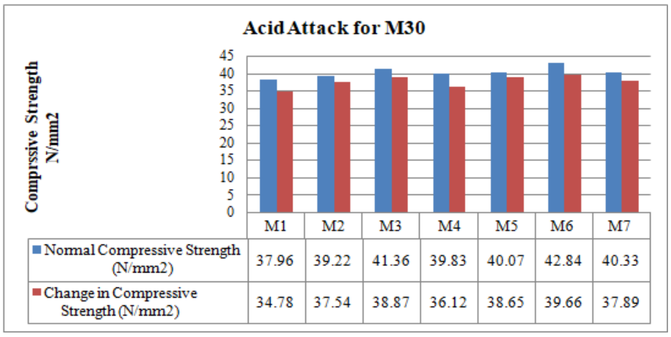

Figure 5.5: Compressive strength of **M30** grade cubes after performing durability test in acid attack

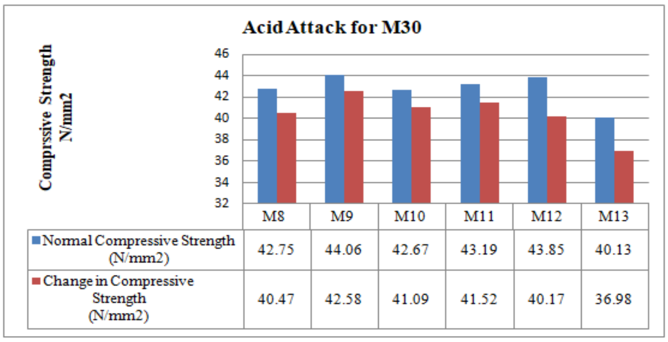

Figure 5.6: Compressive strength of **M30** grade cubes after performing durability test in acid attack

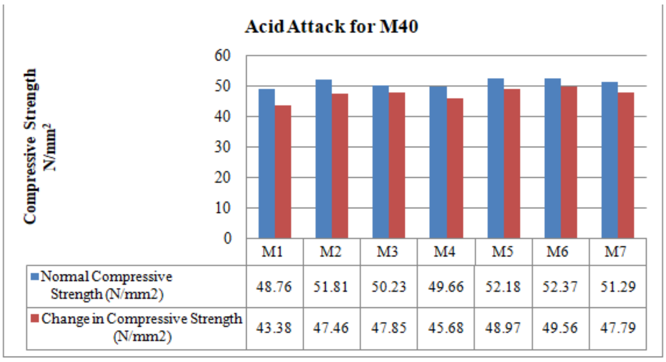

Figure 5.7: Compressive strength of **M40** grade cubes after performing durability test in acid attack

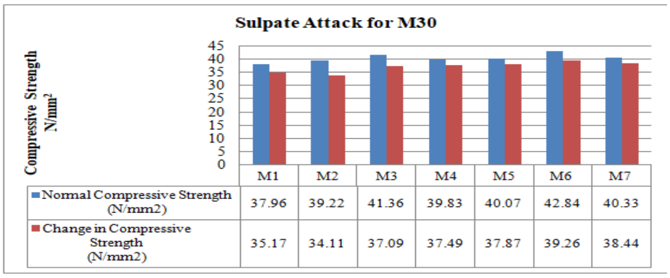

Figure 5.8: Compressive strength of **M30** grade cubes after performing durability test in sulphate attack

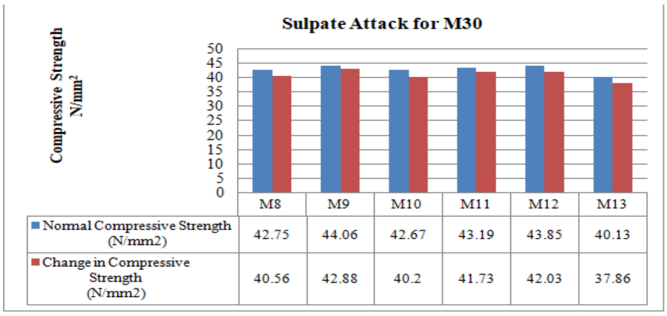

Figure 5.9: Compressive strength of **M30** grade cubes after performing durability test in sulphate attack

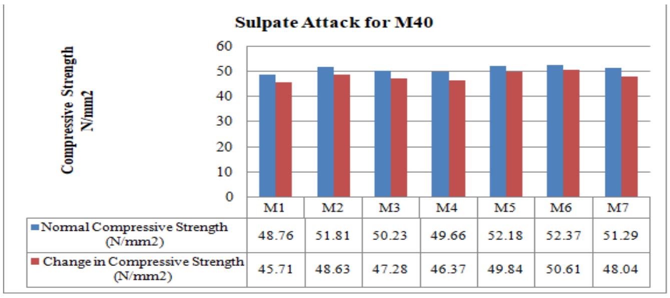

Figure 5.10: Compressive strength of **M40** grade cubes after performing durability test in sulphate attack

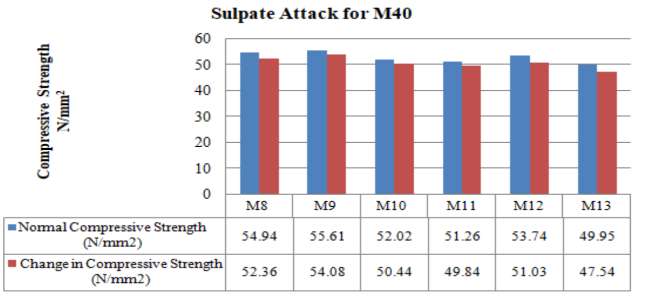

Figure 5.11: Compressive strength of **M40** grade cubes after performing durability test in sulphate attack

CONCLUSIONS

- The workability of the concrete increases with the increase in the copper slag content for M30 and M40 grade concrete and the workability reaches its maximum at 40% replacement of copper slag.
- The result obtained high Compressive strength at 28 days of M30 and M40 grade of concrete is achieved 16% and 14% increment respectively at 15% replacement with zeolite & at 30% replacement with Copper Slag.
- With the use of 15% zeolite and 40% copper slag the split tensile strength is 16.83% more as compare to normal mix of M30 grade of concrete.
- With the use of 10% zeolite and 40% copper slag the split tensile strength is 13.48% more as compare to normal mix of M40 grade of concrete.
- Strength of concrete increasing with replacing by waste material till their optimum replacement limit. If the amount of waste materials replaced increases, the strength decreases.
- After durability test, Concrete losses 3.36% and 2.67% of strength at 28 days compared to 8.35% and 7.34% in normal concrete against acid attack and sulpate attack respectively at 15% replacement with zeolite & at 30% replacement with Copper Slag for M30 grade of concrete.
- Concrete losses 3.12% and 2.75% of strength at 28 days compared to 11% and 6.25% in normal concrete against acid attack and sulpate attack respectively at 15% replacement with zeolite & at 30% replacement with Copper Slag for M40 grade of concrete.

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