A STUDY ON HARDENED PROPERTIES OF CONCRETE WITH PARTIAL REPLACEMENT OF FINE AGGREGATE BY COPPER SLAG AND TILE POWDER

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Abstract : This paper presents results from experimental investigation carried out to study the hardened properties of M25 grade concrete by partial replacement of fine aggregate with Copper Slag(CS) as well as Tile Powder(TP) and to compare the same with that of control concrete by conducting various tests. The strength characteristics of CS incorporated concrete was found out by replacement of 0%, 30%, 35%, 40%,45% and 50 % in Fine Aggregate, Out of these 40% replacement gives highest compression strength at 28 days. The strength characteristics of TP incorporated concrete was found out by replacement of 0%, 10%, 15%, 20% ,25% and 30 % in Fine Aggregate, Out of these 20% replacement gives highest compression strength at 28 days. The Strength of Concrete with varying replacement of fine aggregate from 0%, 30%, 35%, 40%, 45% and 50% was investigated. Again in the above replacements, combinations of TP & CS by 50% TP & 50% CS and 60% TP & 40% CS was studied, Out of these 40% replacement of 50% CS and 50% TP gives highest compression strength at 28 days. Various tests were conducted for above obtained optimum percentages ,such as compressive strength, split tensile strength , modulus of elasticity and flexural strength. Sorptivity test is also conducted for durability check.

Index Terms **- M25 grade concrete, Copper Slag(CS), Tile Powder(TP), durability, Compressive strength, replacement in Fine Aggregate.**

I. INTRODUCTION

Concrete is used widely in the world. The usage of concrete is unavoidable. So, the concrete should be eco-friendly and long lasting. It is used more than any man-made product in the world, and is the second most consumable product in the world, next to water. Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens over period of time. Increased Construction activity and continuous dependence on conventional materials of concrete making are leading to the scarcity of resources and increased Construction cost. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of recycling of waste materials, nonconventional and innovative materials in order to compensate the lack of natural resources and to find alternative ways of conserving the environment. As a part of that many industrial wastes such as stone dust, silica fume, blast furnace slag, steel slag, copper slag, fly ash and ceramic wastes can be used as nonconventional materials as replacement of constituent materials in concrete. In the present investigation, an attempt is made to study the effects of waste by-products of Copper Slag as well as Tile Powder as partial replacement of Fine aggregate in Concrete

II . SIGNIFICANCE OF THIS STUDY

There are many inquiry and study that had carried out to compensate the lack of natural resources and to find alternative ways of conserving the environment by using waste materials. For this study, copper slag from Copper Industry, ceramic tile waste are used as partial Fine Aggregate replacement to natural Fine Aggregate. The study is essential because the proposed materials to replace Fine Aggregate are waste products from the Industries and Construction and Demolition (C&D).If copper slag and ceramic waste is suitable, it can be used in concrete production. This will reduce the waste materials from Industries and C&D as these can be recycled for concrete production purposes. Besides, we can cut down the uses of natural aggregates that are depleting day by day. The concrete's production cost can be reduced because the alternative material is waste material that is very low in cost.

III . MATERIALS

Cement :

The cement used throughout the experimental investigation was Ordinary Portland cement (OPC) of 43 grade conforming to IS : 8112:1989 specifications. The specific gravity of the cement was 3.12. The initial and final setting times were found as 85 minutes and 335 minutes respectively. Normal consistency and fineness values of concrete are found to be 32% and 2.8% respectively.

Fine aggregate :

Locally available river sand passing through 10 mm size conforming to zone II as per IS :383 -1970, has been used. Specific gravity and Fines modulus values are found to be 2.58 and 2.79 respectively. Bulk density was observed to be 1538 kg/m^3**.**

Coarse aggregate :

The graded coarse aggregate of sizes 20mm and 12.5mm were used in this experimental work which is obtained from locally available quarry. Specific gravity for 20mm and Fines modulus was observed to be 2.73 and 6.98 respectively. Water absorption was 0.4% for 20mm and 0.8% for 12.5mm aggregates were arrived. Bulk density values ware observed to be 1493 kg/m^3 for 20mm and 1521 kg/m^3 for 12.5mm size aggregates.

Copper Slag:

Copper Slag is an industrial by-product material produced from the process of manufacturing copper. It is an abrasive blasting **grit**, made of granulated slag from metal smelting processes. For every ton of copper production, about 2.2 tonnes of copper slag is generated. It has been estimated that approximately 24.6 million tons of slag are generated from the world copper industry.Copper slag is obtained from the Sterlite Industries India Limited (SIIL), Tuticorin, Tamil Nadu. Specific gravity and Fines modulus was observed to be 3.48 and 3.25 respectively. Water absorption was 0.18%. Bulk density values ware observed to be 2210 kg/m^3.

Fig.1. Copper Slag

Tile Powder :

Construction and Demolition (C&D) wastes contribute the highest percentage of wastes worldwide (75%). Furthermore, ceramic materials contribute the highest percentage of wastes within the C&D wastes. Ceramic tiles. Waste ceramic tiles are collected from locally available dump sites. Specific gravity and Fines modulus was observed to be 2.4 and 2.67 respectively. Water absorption was 0.05%. Bulk density values ware observed to be 1050 kg/m^3.

Fig 2: Tile Powder

IV.MIX PROPORTION OF MATERIALS

After performing all the required tests on the ingredients of the concrete such as a cement, fine aggregate, coarse aggregate etc. . Mix proportions are calculated for M25 grade concrete. Mix design is done as per IS :10262 -1982.Target mean strength for the designed M25 grade concrete is found to be 33.0 MPa against 31.6 MPa. The quantity of ingredients and their mix proportions are shown in the following Table No.1.

	Cement	Fine Aggregate	Coarse Aggregate	Water
Quantity (kg/m^3)	360	608	1246	180
Mix proportion	**1**	**1.68**	**3.46**	**0.5**

Table.1: Mix proportion of the materials

V. EXPERIMENTAL INVESTIGATION

The composition of the mixes is presented in Table 1. In the present investigation Copper Slag(CS) is added at five proportions to find out the optimum percentage at 7 and 28days. Five proportions are : 0% , 30% ,35% , 40%, 45% and 50% , Then after testing the optimum percentage of Copper Slag is found at 40% . Then, Tile Powder is added at five proportions to find out the optimum percentage at 7 and 28days. Five proportions are : 0% , 10% ,15% , 20%, 25% and 30% ,Then after testing the optimum percentage of Tile Powder is found at 20%.The Strength of Concrete with varying replacement of fine aggregate which consist 50% TP & 50% CS and 60% TP & 40% CS were carried out at 7 and 28days, out of this 40% replacement of 50% CS and 50% TP gives highest compression strength at 28 days. For above obtained optimum percentages, various test conducted for 28 days.

Tests are performed on cured concrete specimens consisting for compressive strength, split tensile strength, flexural strength, Modulus of elasticity and Sorptivity tests. For each mixture ,cube specimen were tested at 7 and 28days and the cylinder , beam and specimens were tested at 28days. For all the tets results were computed from the average of three specimens. Dimensions of the each specimen as follows:

Cube : 150mm x 150mm x 150mm , Beam :500mm x 100mm x 100mm, Cylinder : 150mm x 300mm, Specimen : 95mmx50mm

VI . RESULTS AND DISCUSSIONS

Compressive Strength :

Firstly cube compressive strength test was performed to find out the optimum percentage of copper slag(CS) after 7 and 28 days of curing in water and the results are plotted in the fig.no.3.Then cube compressive strength test was performed to find out the optimum percentage of tile powder(TP) after 7 and 28 days of curing in water and the results are plotted in the fig.no.4.

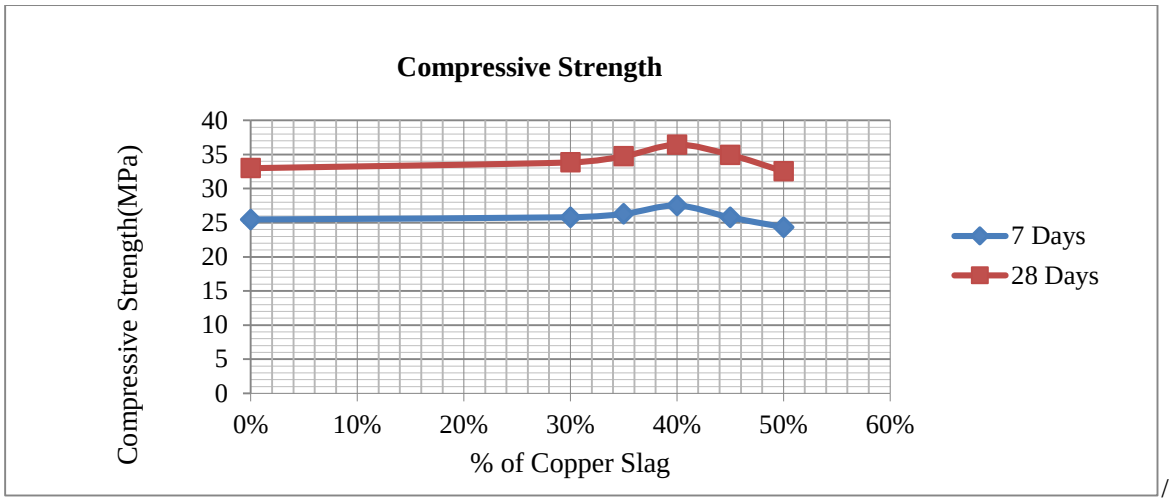

Fig.3: compressive test result for optimum percentage of copper slag

At 7 days of curing, 40% replacement of Fine aggregate with Copper Slag gives a maximum Compressive strength of Concrete **27.54 MPa**, which is 8.08% more compared with Compressive strength of control concrete. At 28 days of curing, upto 40% replacement of fine aggregate with copper Slag, the Compressive strength of concrete in M25 mix was increased. Beyond 40% replacement of copper slag, decrease in Compressive strength was observed. At 40% replacement of fine aggregate with copper Slag, the Compressive strength of concrete **36.44 MPa**, which is 10.42% more compared with control concrete. But at 45% of Fine Aggregate replacement with Copper Slag, 5.93% increase compressive strength is observed compared with control mix. Beyond 45% replacement of fine aggregate by copper slag leads to decrease in compressive strength compared to control concrete.

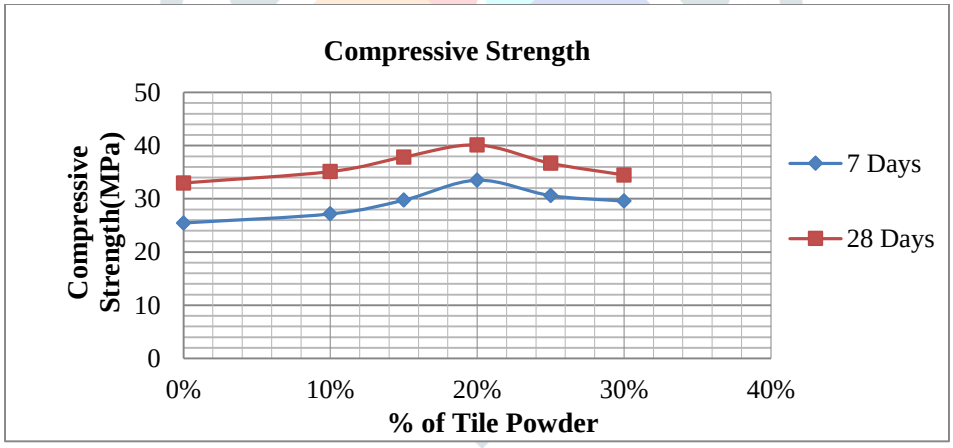

Fig.4: compressive test results for replacement of Tile Powder

At 7 days of curing, 20% replacement of fine aggregate with tile powder gives maximum Compressive strength of concrete **33.51 MPa**, which is 31.51% more compared with Compressive strength of control concrete. At 28 days of curing, upto 20% replacement of fine aggregate with Tile Powder, the Compressive strength of concrete was increased. Beyond 20% replacement of Tile Powder, decrease in Compressive strength was observed. At 20% replacement of Fine Aggregate with Tile Powder, the Compressive strength of concrete **40.14 MPa**, which is 21.63% more compared with control concrete. But at 30% replacement of Fine Aggregate with Tile Powder, 4.54% more compressive strength is observed compared with control mix.

Optimum percentage of Copper Slag and Tile Powder

From the above experimental result of Compressive strength of concrete by partial replacement of Fine aggregate with Copper slag and tile powder, optimum percentage of Copper Slag is obtained as 40% and optimum percentage of tile powder is 20%. By

Adding this optimum percentage of Copper Slag and tile powder together to the concrete and further studies have been conducted on the concrete and results were compared with control concrete.

The tests were conducted for two combinations. Which are

- Copper slag 50% and Tile powder 50%
- Copper slag 40% and Tile powder 60%

Compressive strength of concrete with combination of (CS50% & TP50%) in Fine Aggregate

Compressive strength of M25 grade concrete with various percentages of Copper Slag and Tile Powder were obtained. The test results were plotted with variation of compressive strength of M25 grade concrete with various percentages of Copper Slag and Tile Powder in Fig 5.

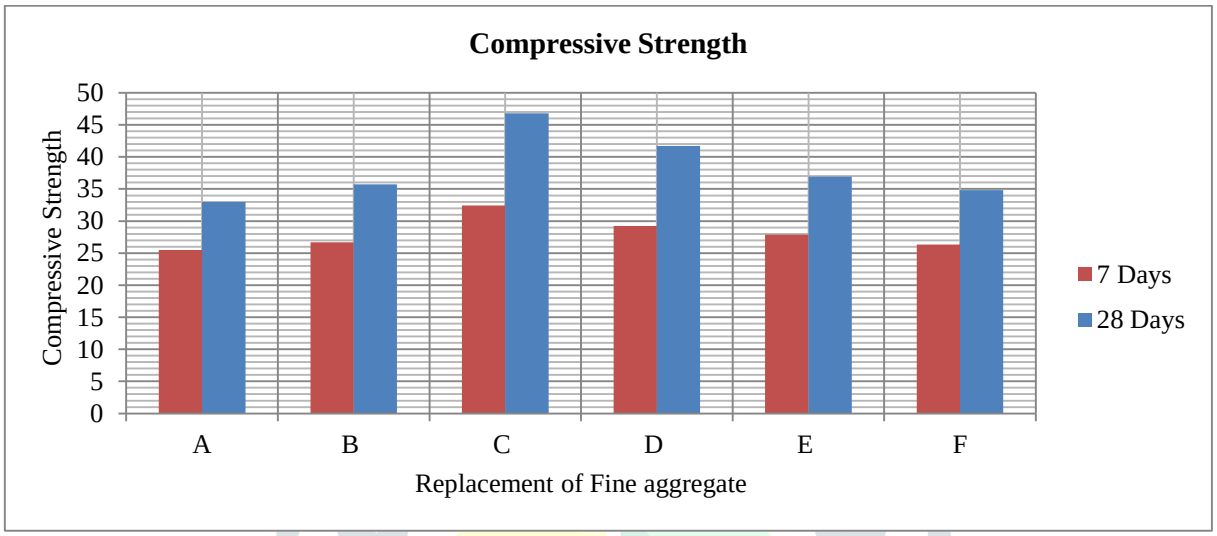

Fig 5: Variation of Compressive Strength Vs Replacement of Fine aggregate (50% Copper slag & 50% Tile powder)

Compressive strength of concrete for partial replacement of varying percentages of Fine Aggregate by Copper Slag 50% + Tile Powder 50% in concrete at 7 and 28 days of curing is conducted. Maximum compressive strength of **32.44 MPa & 46.8 MPa** respectively is observed at 35 % replacement of Fine aggregate, which is 27.3% & 41.8% increase when compared with control concrete respectively. Compressive strength of concrete for 50% replacement of Fine Aggregate by Copper Slag 50% + Tile Powder 50% in concrete at 7 and 28 days is **26.36 MPa & 34.8 MPa** respectively is observed, which is 3.45% & 5.45% increase when compared with control concrete respectively.

Compressive Strength of concrete with combination of (CS40% & TP60%) in Fine Aggregate

The test results of compressive strength of M25 grade concretes with various percentages of Copper Slag and Tile Powder were obtained. The test results are plotted with variation of compressive strength of M25 grade concrete Vs various percentages of Copper Slag and Tile Powder in the Fig 6.

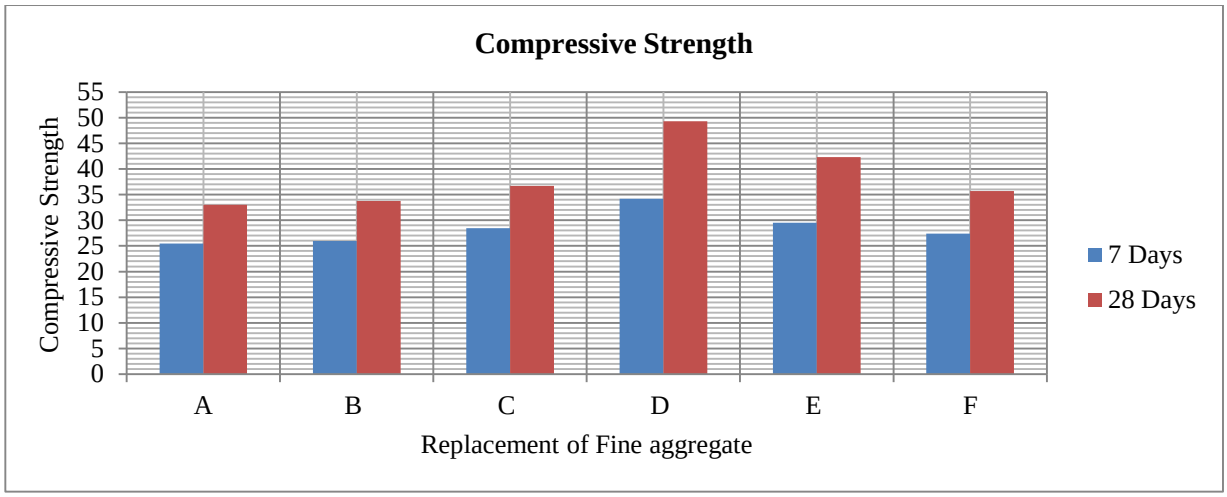

Fig 6: Variation of Compressive Strength Vs Replacement of Fine aggregate (40% Copper slag & 60% Tile powder)

Compressive strength of concrete for partial replacement of varying percentages of Fine Aggregate by Copper Slag 40% + Tile Powder 60% in concrete at 7 and 28 days of curing is conducted. Maximum compressive strength of **34.22 MPa & 49.30 MPa** respectively is observed at 40 % replacement of Fine aggregate, which is 34.3% & 49.3% increase when compared with control concrete respectively. Compressive strength of concrete for 50% replacement of Fine Aggregate by Copper Slag 40% + Tile Powder 60% in concrete at 7 and 28 days is **27.40 MPa & 35.70 MPa** respectively is observed, which is 7.53% & 8.18% increase when compared with control concrete respectively.

Split Tensile Strength

Split tensile strength of specimens with obtained optimum percentages are performed at 28 days and compared with control mix. The test results are plotted in the fig.no.7

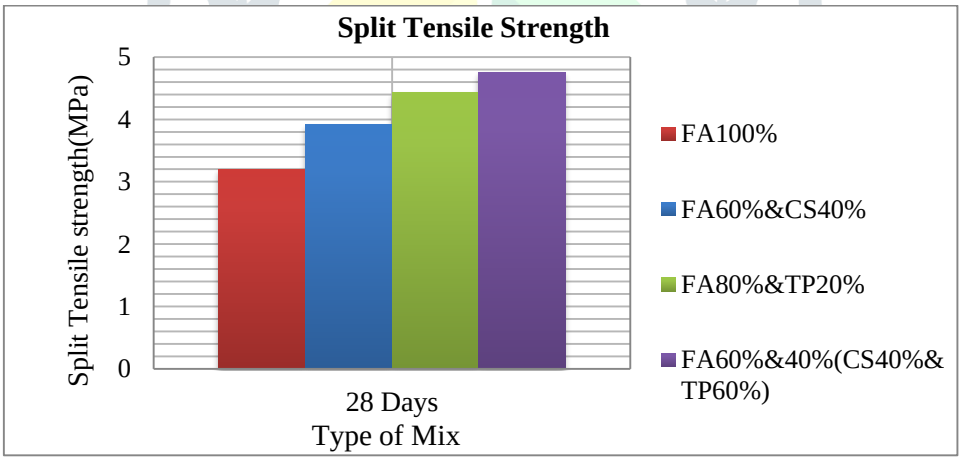

Fig.7: Variation of Split tensile strength Vs Age of Concrete with Replacement of Fine aggregate by Copper slag & Tile powder

For M25 Grade concrete, Split tensile strength of **3.91 MPa** is observed at 40% replacement of copper slag in fine aggregate, which is 22.18% more compared with control concrete. Split tensile strength of **4.43 MPa** is observed at 20% replacement of tile powder in fine aggregate, which is 38.43% more compared with control concrete. Maximum Split tensile strength of **4.76 MPa** is observed at 40% replacement of Fine aggregate which includes 40% ***Copper Slag*** and 60% ***Tile Powder*** at 28 Days, which is 48.75% more compared with Split tensile strength of control concrete.

Flexural Strength

Flexural strength of specimens with obtained optimum percentages are performed at 28 days and compared with control mix. The test results are plotted in the fig.no.8

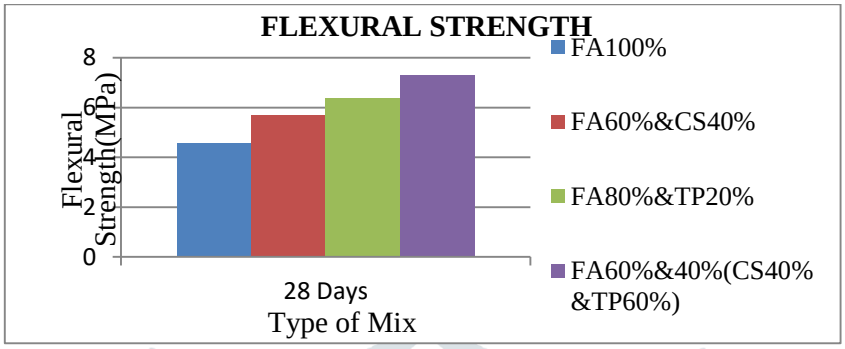

Fig.8: Variation of Flexural Strength Vs Age of Concrete with Replacement of Fine aggregate by Copper slag & Tile powder

For M25 Grade concrete, Flexural strength of **5.70 MPa** is observed at 40% replacement of copper slag in fine aggregate, which is 25.55% more compared with control concrete. Flexural strength of **6.36 MPa** is observed at 20% replacement of tile powder in fine aggregate, which is 40.08% more compared with control concrete. Maximum Flexural strength of **7.29 MPa** is observed at 40% replacement of Fine aggregate which includes 40% ***Copper Slag*** and 60% ***Tile Powder*** cured upto 28 days, which is 60.57% more compared with Flexural strength of control concrete.

Modulus of Elasticity

Modulus of elasticity test was performed on standard cylinder specimens at 28 days of curing and compared with control concrete. The test results are plotted in the fig.no.9

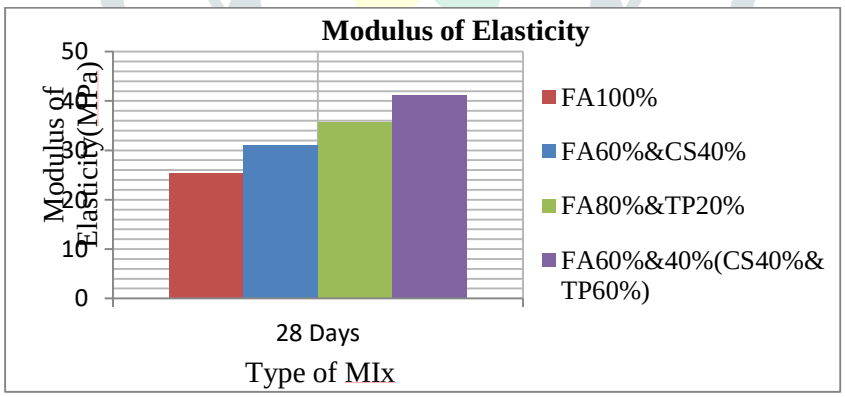

Fig.9: Variation of Modulus of Elasticity Vs Age of concrete with replacement of

Fine aggregate by Copper slag & Tile powder

For M25 Grade concrete, Modulus of elasticity of **31.00 MPa** is observed at 40% replacement of copper slag in fine aggregate, which is 21.71% more compared with control concrete. Flexural strength of **35.75 MPa** is observed at 20% replacement of tile powder in fine aggregate, which is 40.36% more compared with control concrete. Maximum Modulus of elasticity of **41.24 MPa** is observed at 40% replacement of Fine aggregate, which includes 40% ***Copper Slag*** and 60% ***Tile Powder*** cured upto 28 days, which is 61.91% more compared with Modulus of elasticity of control concrete

Sorptivity

The sorptivity of standard specimens was conducted for durability check after 28 days of curing and compared with control concrete. The test results are plotted in the fig.no.10.

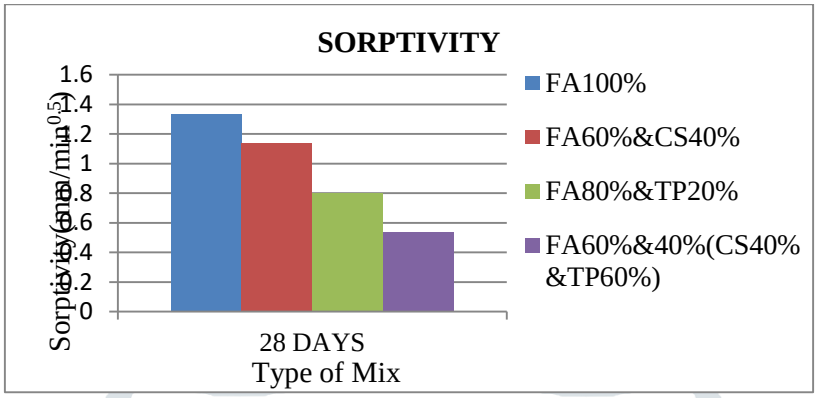

Fig.10: Variation of Modulus of Elasticity Vs Age of concrete with replacement of Fine aggregate Copper slag & Tile powder at 28 Days

The Percentage in water absorption of concrete cubes prepared with optimum percentages of Copper Slag and Tile Powder time period at 28 days curing for M25 grade concrete gives that Percentage loss in water absorption of **1.137 mm/min$^{0.5}$** is observed at 40% replacement of Fine aggregate by copper slag, which is 14.83% more compared with control concrete. Percentage loss in water absorption of **0.802 mm/min$^{0.5}$** is observed at 20% replacement of Fine aggregate by tile powder, which is 39.92% more compared with control concrete. Maximum percentage loss in water absorption of **0.536 mm/min$^{0.5}$** is observed at 40% replacement of Fine aggregate which includes 40% ***Copper Slag*** and 60% ***Tile Powder*** cured upto 28 days, which is 73.4% less compared with Modulus of elasticity of control concrete.

VII . CONCLUSIONS

The following conclusions were drawn after the laboratory investigations:

1. The compressive strength increased 10.42% with the replacement of Copper Slag in Fine aggregate at 28 Days as compared to the conventional concrete.
2. The compressive strength increased 21.63% with the replacement of Tile Power in Fine aggregate at 28 Days as compared to the conventional concrete.
3. The compressive strength increased 41.8% with the replacement of 35% of 50% Tile Powder & 50% Copper Slag in Fine aggregate at 28 Days as compared to the conventional concrete.
4. The compressive strength increased 49.3% with the replacement of 40% of 60% Tile Powder & 40% Copper Slag in Fine aggregate at 28 Days as compared to the conventional concrete.
5. The Split Tensile Strength increased 48.75% with the replacement of 40% of 60%Tile Powder and 40% Copper Slag in Fine aggregate at 28 Days as compared to the conventional concrete.
6. The Flexural Strength increased 60.57% with the replacement of 40% of 60%Tile Powder and 40% Copper Slag in Fine aggregate at 28 Days as compared to the conventional concrete.

7. The Modulus of Elasticity increased 61.91% with the replacement of 40% of 60%Tile Powder and 40% Copper Slag in Fine aggregate at 28 Days as compared to the conventional concrete.
8. Water absorption has reduced with the replacement of 40% of 60% Tile Powder and 60% Copper Slag in Fine aggregate upto 73.4% compared with control concrete at 28 Days as compared to the conventional concrete.

VIII . RECOMMENDATIONS FOR FUTURE RESEARCH

The present experimental work can be extended to different Grades of Concrete with the use of chemical Admixtures to the concrete. Strength and durability properties of Copper Slag concrete by adding non-metallic and organic fibres can be studied.This work can be extended further by adding some other materials in addition to the Copper Slag and Tile Powder.

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