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To Study the Partially Replacement Cement with Metakaolin, Egg Shell Powder and Fine Aggregates with Washed Bottom Ash

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Abstract: ***Nowadays due to the construction boom demand for this material increasing day by day for construction activities worldwide, for rapid growth in infrastructure, consumption of natural sand is increased which lead to the continuous extraction of natural sand from the river bed. Due to these adverse effects, different states have imposed bans on the natural extraction of sand. The portion of the ash that escapes the chimney is referred to as fly ash (80%), and the clinkers that fall under their weight in the bottom hopper is termed as bottom ash (20%) which is cooled by water washing and is termed as Washed Bottom Ash (WBA). The most effective pozzolanic substance for use in concrete is metakaolin, a kind of pozzolana. it is known that the eggshell is mainly has the composition of compounds of calcium. Eggshells are composed of 93.70% calcium carbonate (in calcium), 4.20% of it is organic matter, 1.30% is magnesium carbonate, and 0.8% of it is calcium phosphate. The partial replacement of aggregates is need for the future generation of concrete structures for the environment supportable. The depletion of the natural resources gets exhausted. We have think over the alternate replacement of the materials. In present work the partial replacement of the metakaolin, Esp with the Cement and the fine aggregates is partially replaced by the WBA. Optimum value of strength in compression, split tensile and flexure came at MK,ESP12%WBA35% replacement of the TWA with the Cement and the fine aggregates is partially replaced by the WBA. The workability of mixture increases and after that there is decrease in the workability of the concrete when we increase the percentage of MK,ESP and WBA. A series of experiment were carried out to measure the compressive strength, split tensile strength and flexural strength of the concrete. The results showed that the compressive strength, split tensile strength and flexural strength increases with the adding of the MK,ESP and WBA in concrete.***

Keywords: MK (METAKAOLIN), ESP (EGG SHELL POWDER), WBA (WASHED BOTTOM ASH) workability, compressive strength, Split Tensile strength, Flexural strength.

I. INTRODUCTION

On the other hand, one cannot think of producing concrete without cement as it is the only binding material between fine and coarse aggregate in concrete. The manufacturing of cement poses a severe threat to the environment. It is estimated that nearly 1 tonne of CO2 gas gets emitted during 1 tonne of Portland cement production. Emission in the air is the major challenge faced by the cement industry, which leads to air pollution. When cement dust is being drained, it contaminates the water and causes adverse effects on human well-being and animals. So, the need arises for supplementary cementing material, which can replace cement and enhance concrete's mechanical properties. Some materials that have already been used to replace natural sand, such as fly-ash, quarry dust or limestone, siliceous stone powder, filtered sand, and copper slag, are used in concrete and mortar mixtures. One of the materials which can also be effectively used as a replacement for sand in concrete is Washed Bottom Ash (WBA), and metakaolin, ESP powder can be used as a replacement for cement because metakaolin, ESP is finer than cement particles which makes concretely impermeable due to which strength of concrete increase. Since metakaolin is a new material that is not a by-product and nor natural it is produced by calcination of kaolinite clay. Cement concrete is mostly used worldwide and its maintenance and repair work cause problems that cause an increase in expenditure. Addition of metakaolin in cement concrete satisfy more stringent performance requirements, especially long–term durability

A. Washed Bottom Ash (WBA)

India produces approximately more than 100 million tonnes of coal ash annually. Coal-based thermal power plants all over the world face serious problems of handling and disposal of the ash produced.

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The utilization of fly ash is about 30% as various engineering properties requirements that is for low technical applications such as in the construction of fills and embankments, backfills, pavement base and sub-base course. Washed bottom ash is nearly 20% of the residual material of coal combustion in a power plant, boiler, furnace, or incinerator. The portion of the ash that escapes the chimney is referred to as fly ash (80%), and the clinkers that fall under their weight in the bottom hopper is termed as bottom ash (20%) which is cooled by water washing and is termed as Washed Bottom Ash (WBA). India currently generates 100 million tonnes of coal ash annually, of which 15-20% is bottom ash. Non-natural lightweight aggregate built on bottom ash has a lot of promise for usage in construction projects.

B. Metakaolin Powder

By using additives in place of cement, which increases CO2 emissions in the construction industry, these emissions are reduced. Cement can be replaced with metakaolin, also known as calcined kaolin, which is created via calcination. Due to their advantages for the economy and ecology, supplemental cementitious elements are utilised in concrete all over the world and have received a lot of attention recently. The more popular SCMs are mineral admixtures such fly ash, rice husk ash, silica fume, etc. They aid in achieving increased efficiency and performance. One such unconventional substance that can be used to good effect in the construction sector is metakaolin.

C. EGG SHELL

If we talk about egg production then India comes at the fifth position with an annual rate of egg production amounts at 1.61 million tonnes. Both poultry and egg processing units have come predominantly in India. Andhra Pradesh stands at the top among all eggshell producers in India. The maximum egg production in Andhra Pradesh accounts for one-third of the country„s daily production of 5.5 crores of the State„s total production, nearby districts accounted for 3 crore eggs a day, Hyderabad at one and half crore and Telangana district produced 40 lakh. Hyderabad is the city with the maximum number of poultries and hatcheries in Andhra Pradesh. The state is cheering up the large players in the poultry and meat sector to achieve an annual growth rate of 6% in egg production, 10 % in Broiler production, and 2.5 % in meat production for the next 20 years. Scientists have been investigating the beneficial use of Egg shells in construction purposes or other related purposes and it is known that the eggshell is mainly has the composition of compounds of calcium. Okonkwo et al (2012) presented eggshells are composed of 93.70% calcium carbonate (in calcium), 4.20% of it is organic matter, 1.30% is magnesium carbonate, and 0.8% of it is calcium phosphate.

II. LITERATURE REVIEW

Meghana. K et al. (2019): The M30 grade of concrete is used in this investigation for the experiment. 0 percent, 20 percent, 40 percent, 60 percent, 80 percent, and 100 percent of the bottom ash is added in place of the sand. The silica fume is added to replace 20% of the cement's weight in cement in a partial replacement. Additionally, the strength characteristics of concrete, including its impact, flexural, shear, and tensile strength, are investigated. The slump cone test, compaction factor test, and Vee-Bee consistometer test are other methods used to study the workability features. The results of this experiment demonstrate that bottom ash can substitute sand up to 40% of the time while still producing concrete with the desired strength.

M. Narmatha, Dr. T.Felixkala (2016): This study aims to describe the effect of the replacement of metakaolin powder in cement. Metakaolin is a supplementary cementitious material for high- performance concrete. Properties of concrete with metakaolin are mostly preferred additives in high- performance concrete. The replacement proportion of metakaolin to be used was 5%, 10%, 15%, and 20% by the weight of cement. To make these cubes and cylinders to determine the strength and durability of concrete such as compressive strength and tensile strength. The result of this study shows that when 15% of cement is replaced with metakaolin improves the compressive strength and split tensile strength of concrete.

N.Ramkumara Dr.M.Manikandan The main objective of this investigation is to examine the properties of CSFB concrete. T. Karun Kumar, N. Priyanka (2017): In this study, test have been done on concrete with the few amount of replacement of cement is being donw by ESP (0-30%) and copper slag is used in the fine aggregate by maintaining the partial replacement (0-30%). The optimum compression strength is reached at the 20% (10% ESP + 10% CS) replacement. Split Tensile strength for the cylindrical specimens is, Maximum at 40% (20% ESP + 20% CS) replacement for 28 days of curing. The flexural strength of concrete is maximum at 40% (20%ESP + 20% CS) replacement for duration of 28 days of curing.

Syed Saad Ali, Mohd Imran, Boda Vinod, Ramavath Sanjeev, Shaik Abdul
Rasheed, Mohd Ismail Khan 2019: In this study, test was done on concrete with partial replacement of cement with ESP in the proportion of (0-20%) and fine aggregate with Copper scum (0-20%).

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Slump cone value for the copper slag and ESP increases with increasing in the percentage of ESP and copper slag so the concrete was not workable. The value of the Compaction factor test about copper slag and egg shell powder decreases with increase in the percentage of both copper slag and ESP in the concrete. The compressive strength of concrete is find out to be optimum at 10% replacement of copper slag and egg shell powder and is the optimum value after 7 days curing and 28 days curing. The split tensile strength of concrete is find out to be optimum at 15% replacement of copper slag and egg shell powder for 28 days curing in M30 grade concrete and maximum at 10% replacement of copper slag and egg shell powder for 28 days curing. So, the replacement of 10% to 20% of copper slag and egg shell powder is useful for better strength values in M30 grade of concrete.

III. MATERIALS

A. Cement

It serves as a binder. Cement provides sufficient strength once it has hardened. Lime is the main chemical component of cement. Depending on the demand and required strength, there are many different types of cement available on the market. The cement we'll use in this study is 43 Grade Ordinary Portland Cement that complies with IS: 8112 and goes by the brand name Ambuja Cement. The relevant lab has provided information on the cement's physical qualities.

B. Coarse Aggregates

Aggregate which has a size larger than 4.75 mm or which retrained on 4.75 mm IS Sieve are known as Coarse aggregate. Coarse aggregates must be tough, pristine, and devoid of any chemical coating of clay and dust on the surface in order to make a decent concrete mix. Although there are many different ingredients or components used to make concrete mix, coarse aggregate is frequently used because it is one of the most important elements of concrete and takes up a significant amount of the mixture. Grading of coarse aggregate was done according to IS:383-1970. Aggregates of Nominal size 20mm & 10mm to form a graded aggregate. The concerned lab provided the properties of coarse aggregate.

C. Fine Aggregates

Fine aggregate consists of crushed sand particles or natural river sand passing through a 4.75mm sieve. In general, river sand is used as a fine aggregate having a particle size of 0.07mm. The extraction is done from rivers, lakes or seabeds. Fine aggregate that was present at the site was extracted from Akhnoor Jammu. Sieve analysis would be done to find out the zone conforming IS: 383-1970. The physical properties of sand were provided by the concerned lab.

D. Metakaolin Powder

Metakaoline is a highly pozzolanic material. It is one of the most widely used mineral admixtures these days. Concrete containing metakaolin as cement replacement upto some percentage help concrete to obtain both high performance and economy. It is neither a by-product of industry nor a natural product it is obtained by calcination of pure kaolinite or china clay at a temperature of 650 to 800^0C. Once the burning process is completed is grinded properly to that particle size for which it is used and fulfills the strength and property parameter of cement in motar and concrete.

Table no. 1 Properties of metakaolin powder

Chemical Composition	Cement (%)	Metakaolin (%)
Silica (SiO_2)	34	54.3
Alumina (Al_2O_3)	5.5	38.3
Calcium oxide (CaO)	63	0.39
Ferric oxide (Fe_2O_3)	4.4	4.28
Magnesium oxide (MgO)	1.26	0.08
Potassium oxide (K_2O)	0.48	0.5
Sulphuric anhydride (SO_4)	1.92	0.22
Loss on Ignition	1.3	0.68
Specific Gravity	3.15	2.5
Physical Form	Fine Powder	Powder
Colour	Grey	Off White

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E. EGG SHELLS POWDER (ESP)

Eggshells are agricultural dump objects produced from poultries, bakeries, fast food restaurants among others. Its damping on th open land can damage the surroundings and as a result comprising ecological issues/contamination which would need an appropriate diffusion into atmosphere. This created different environmental and health problems. Instead of damping it in land, it can be used in the construction as a binding material with cement.

Table no. 2 Properties of ESP

S.No	Composition	Percentage(%)
1.	CaO	53%
2.	MgO	1%
3.	SiO_2	1.5%
4.	Al_2O_3	0.28%
5.	Fe_2O_3	0.36%
6.	Cl	0.011%

F. Washed Bottom Ash (WBA)

Washed bottom ash is nearly 20% of the residual material of coal combustion in a power plant, boiler, furnace, or incinerator. The portion of the ash that escapes the chimney is referred to as fly ash (80%), and the clinkers that fall under their weight in the bottom hopper is termed as bottom ash (20%) which is cooled by water washing and is termed as Washed Bottom Ash(WBA). The size of bottom ash ranges from fine sand to fine gravel and has a minimal amount of silt and clay. A large portion of bottom ash comprises fine particles. Coal bottom ash is generally falling in a well-graded sand group.

Table no. 3 Properties of WBA

Chemical Composition (%)	Bottom Ash
SiO2	68
Al2O3	25
Fe2O3	2.18
CaO	1.66
TiO2	1.45
MgO	0.02
SO3	Nil
Loss on Ignition	1.69

IV. METHODOLOGY

A. Mixing Concrete

All the ingredients of concrete are mixed together however this mix should be homogenous and uniform in color and consistency. The mixing can either be done by hand or with the use of mixer.

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B. Mixing Concrete

Thorough mixing of the materials is essential to produce uniform concrete. The mixing should make sure that the mass become homogeneous, uniform in consistency and colour. There are two methods adopting for mixing concrete one is hand mixing and other is machine mixing.

C. Curing

Before removing the mould, it is dried for 24 hours, and then specimens are placed in a water tank made to cure specimens. The specimens must be marked for identification so that there must not be any error. The specimens are removed from the tank and dried before putting in the testing machine. The specimens are kept in the tank for 7,14,28 days.

D. Workability Test

It can be used in site as well as in lab. This test is not applicable for very low and very high workability concrete. It consists of a mould that is in the form of frustum having top diameter of 10cm, bottom diameter of 20cm and height of 30cm. The concrete to be tested if fitted in the mould in four layers. The each is compacted 25 times with the help of tamping rod. After the mould is completely filled it is lifted immediately in the vertically upward direction which causes the concrete to subside.

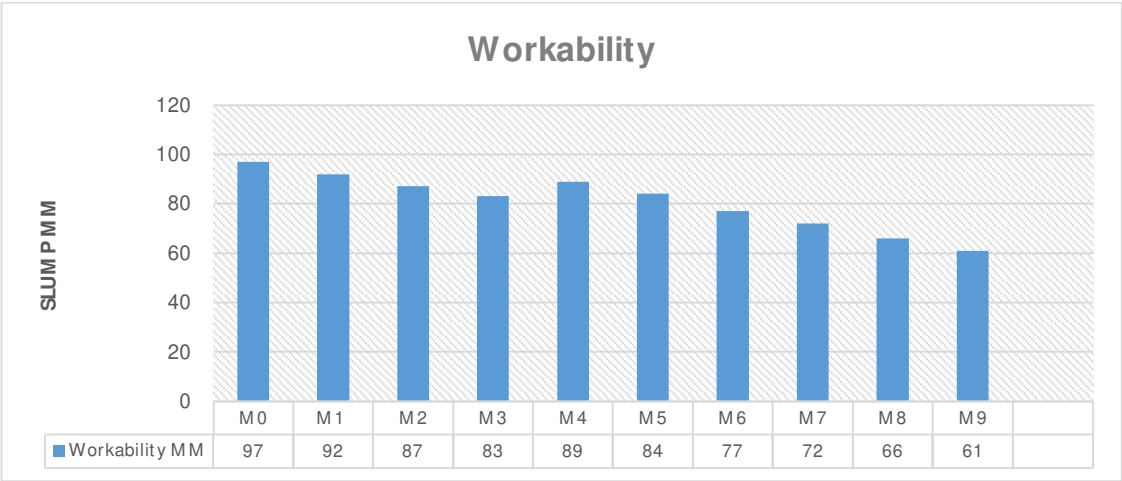

Fig -1: SLUMP CONE TEST

E. Compressive Strength Test

Then fresh concrete is filled in mould in 4 layers and after filling each layer tamping should be done 35 times in case of cube and 25 times in case of cylinder by using standard tamping rod. Once the mould is filled then leveled top surface of concrete with trowel. After the day the mould will removed and specimen are dropped in the curing tank under standard temperature of 27±2° c. After 7,14 days and 28 days in this research.

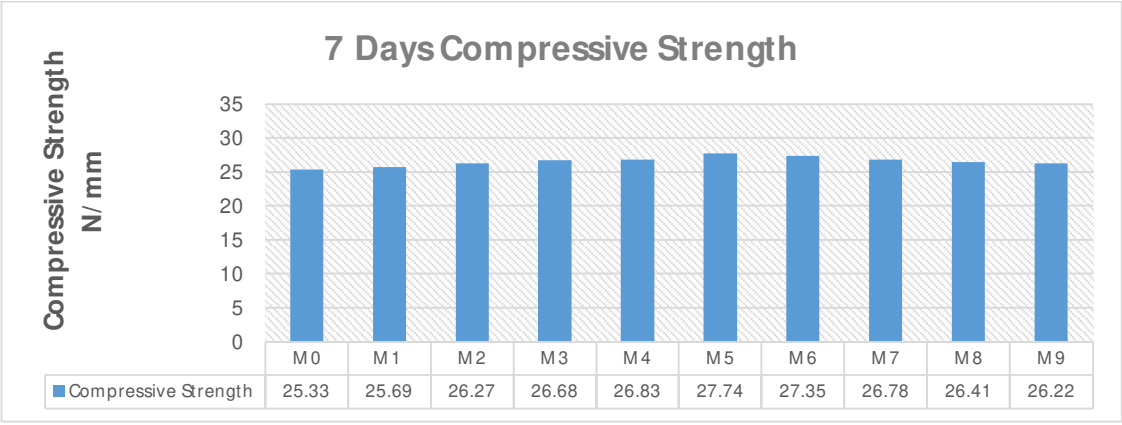

Fig -2: COMPRESSIVE STRENGTH TEST 7

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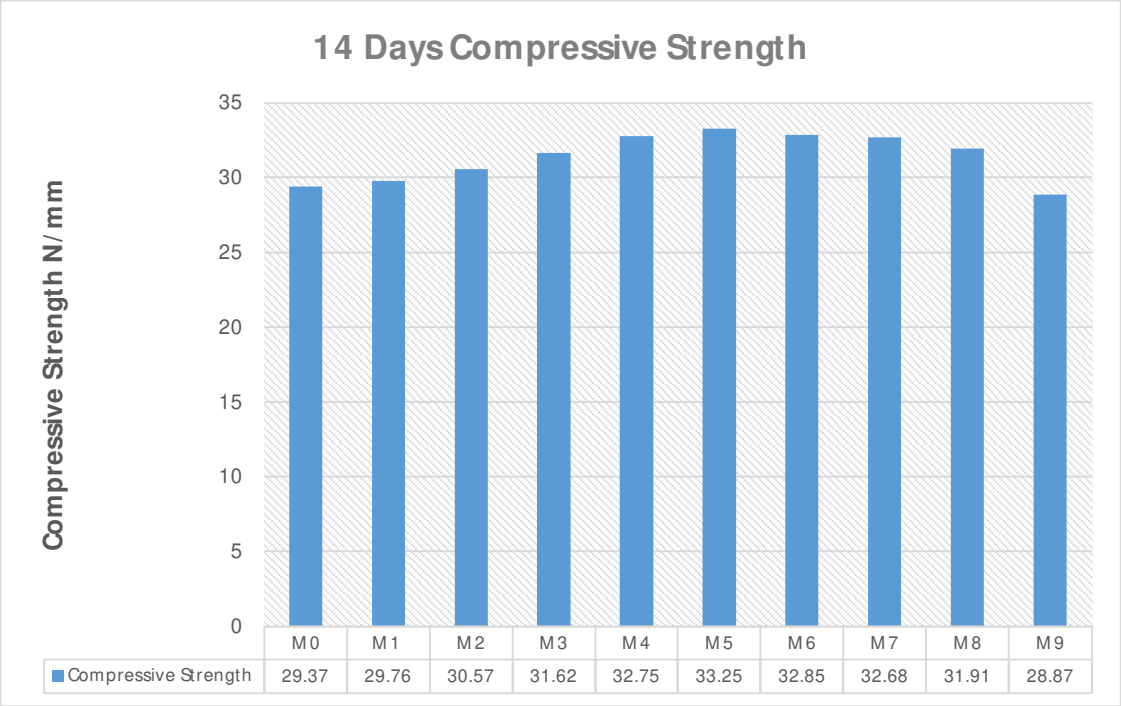

Fig -3: COMPRESSIVE STRENGTH TEST 14

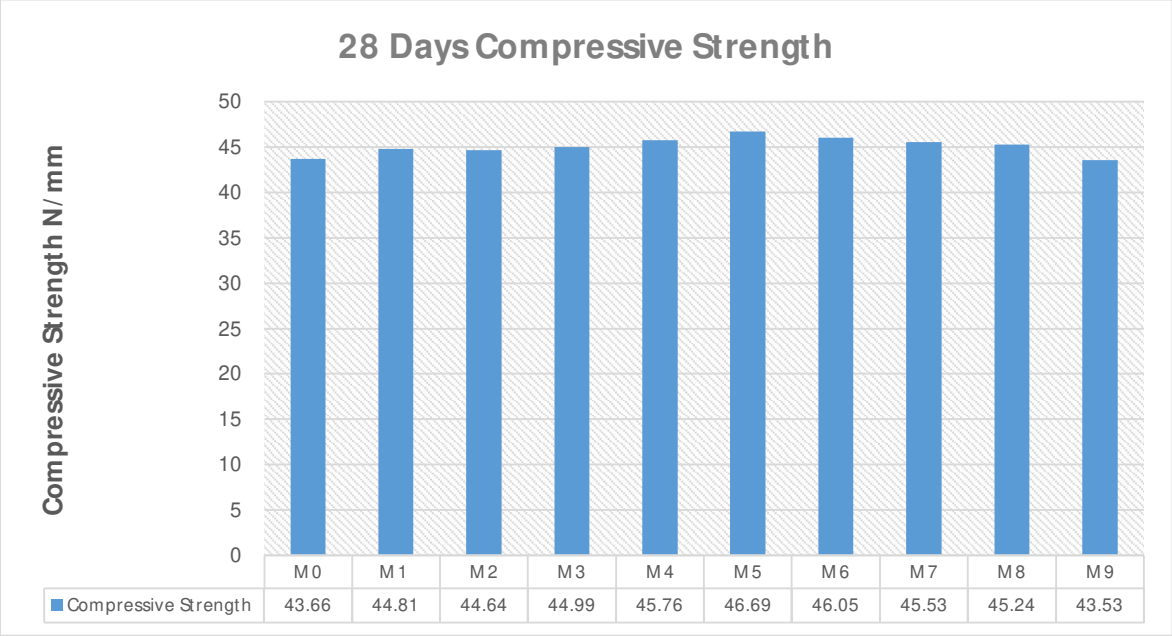

Fig -4: COMPRESSIVE STRENGTH TEST 28

F. Split Tensile Strength Test

The specimen used for this test is cylindrical and its dimension is 150 mm in diameter and 300mm in length. The instrument used for this testing is universal testing machine. The fresh concrete is prepared in according to the required grades and respective mix proportion. The fresh concrete is filled in mould in layers and each layer is tamping with standard tamping rod with 25 blows for each layer. After the day the mould is removed and specimen is placed in the curing tank for 7,14 days and 28 days in this research at the temperature 27+ 2°c. Then draw the line on the specimen.

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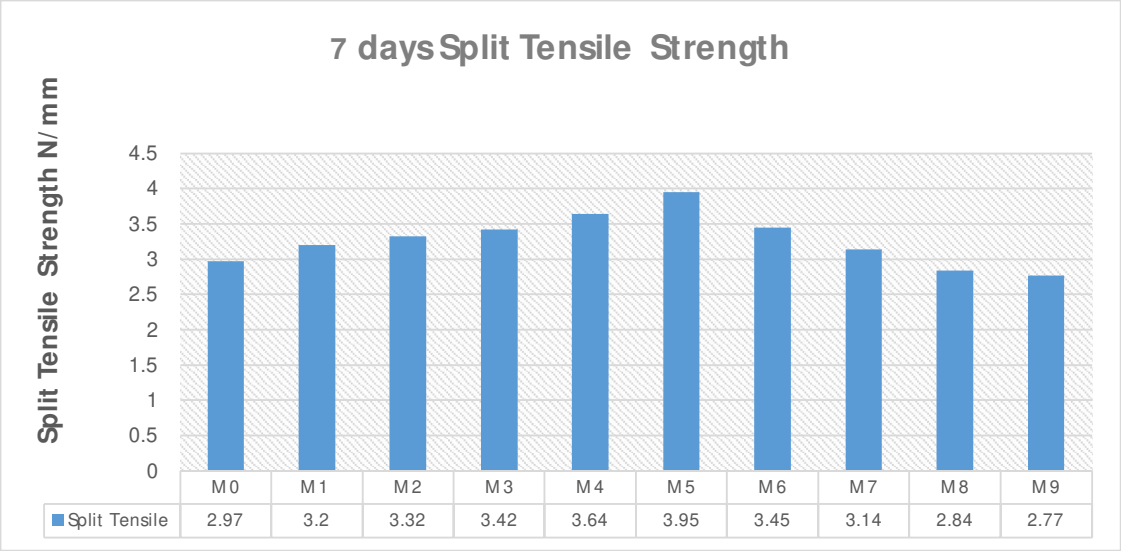

Fig -5: SPLIT TENSILE STRENGTH TEST 7

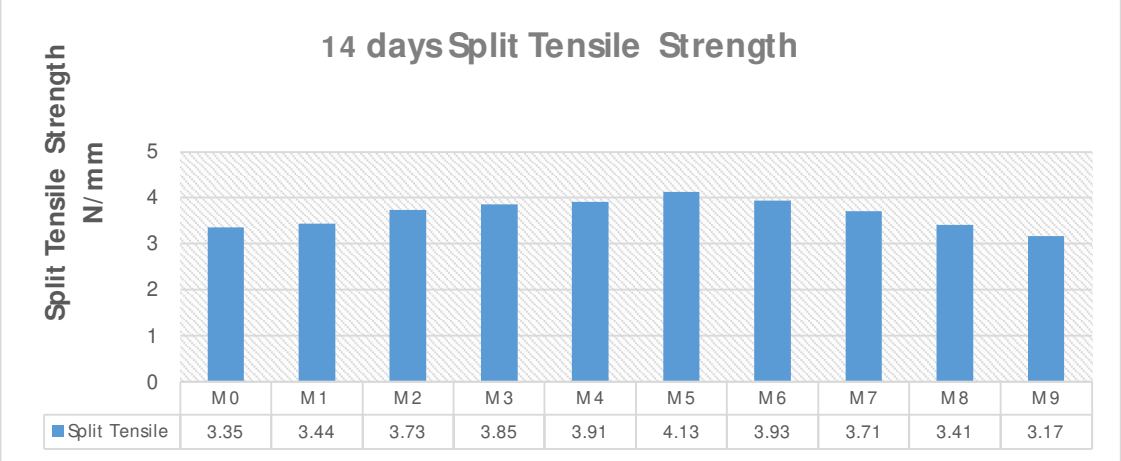

Fig -6: SPLIT TENSILE STRENGTH TEST 14

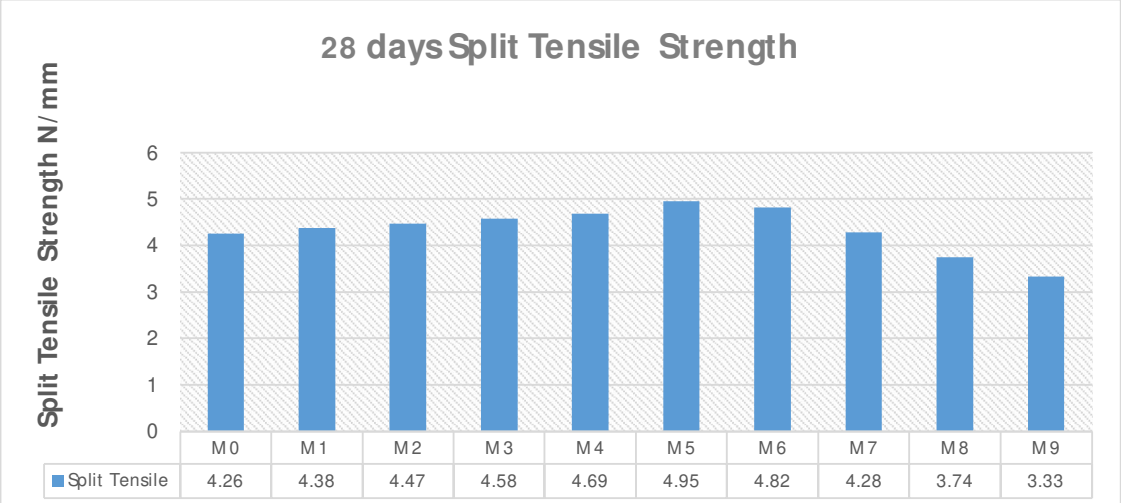

Fig -7: SPLIT TENSILE STRENGTH TEST 28

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G. Flexural Strength Test

The concrete is prepared at required rate of mass element the mould is filled with concrete in layers and blows 25 times with standard tamping rod. After the day or we can say 24 hours the mould is removed and specimen placed in the water tank for curing at a temperature of 27 + 2 C. Depending upon the requirement the test specimen is removed from the water tank and wipe it properly for 7,14 and 28 days for testing.

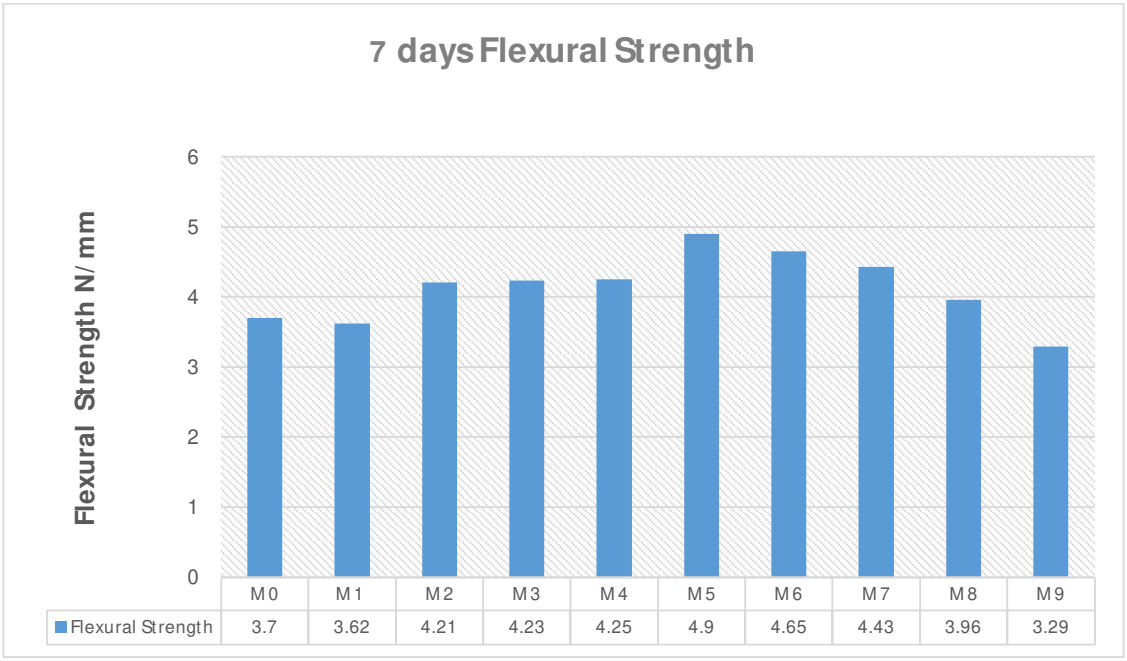

Fig -8: FLEXURAL STRENGTH TEST 7

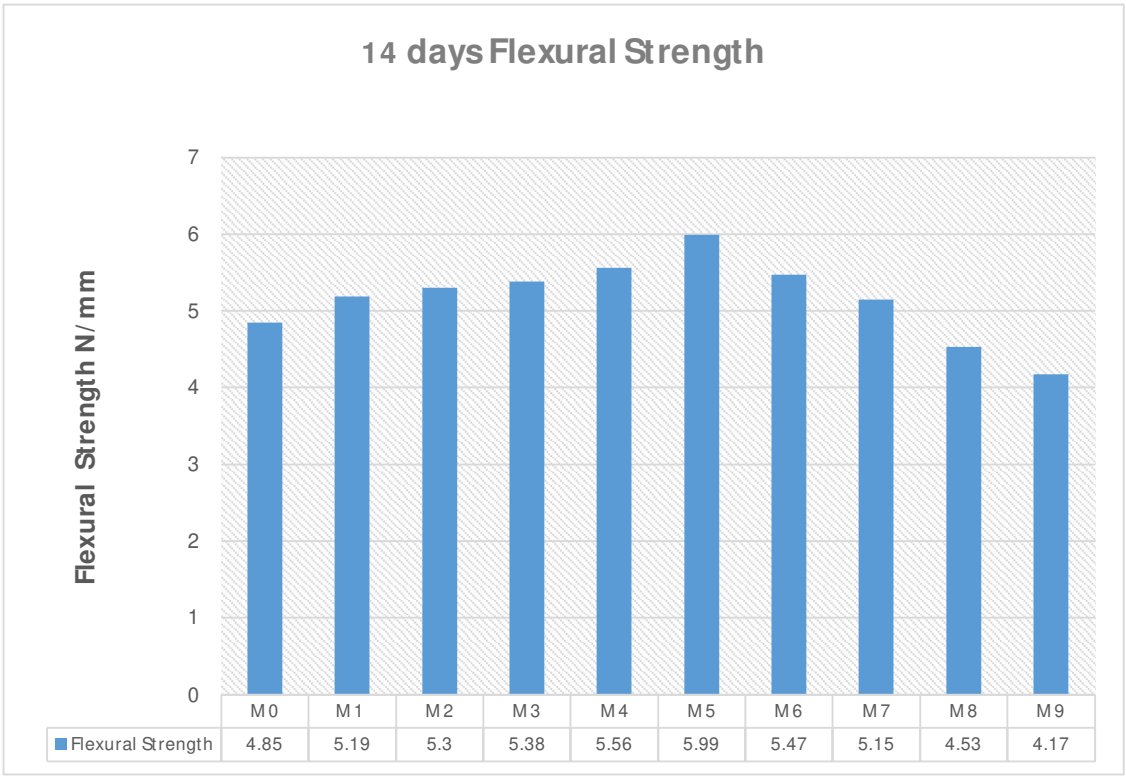

Fig -9: FLEXURAL STRENGTH TEST 14

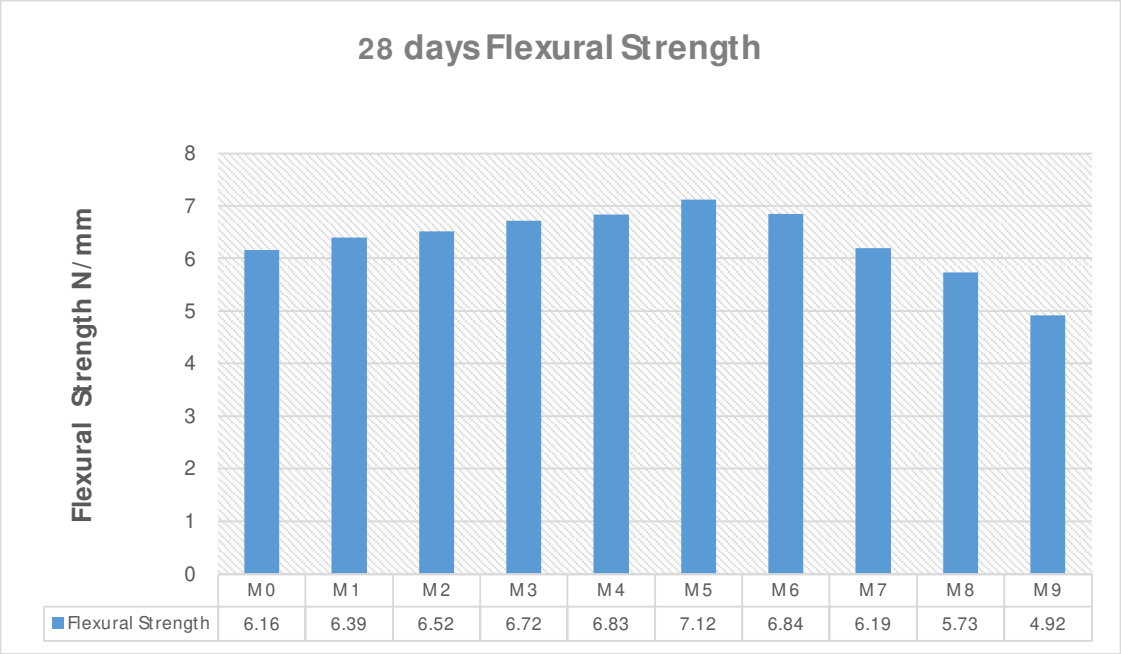

Fig -10: FLEXURAL STRENGTH TEST 28

V. CONCLUSION

By replacing the cement with the replacement of Egg shell & Metakaolin powder with cement and Washed bottom ash strengths get increased, also the replacement can be taken into consideration up to certain percentage workability factors gets enhanced as well.

1) The compressive strength of the concrete on comparing with conventional concrete gets increased till replacement of 12% Egg shell & Metakaolin powder with cement and 35% Washed bottom ash was used. The strength obtained at 7^{th} day is 28.14 N/mm^2.
2) After 14 days of curing, the maximum compressive strength obtained was 33.25 N/mm^2 for same replacements and addition.
3) After 28 days of curing, maximum compressive strength obtained was 47.69 N/mm^2.
4) In case of compressive strength, the optimum percentage that was noticed, was at replacement of 12% Egg shell & Metakaolin powder with cement and 35% Washed bottom ash.
5) The flexural strength of the concrete on comparing with conventional concrete gets increased till replacement of 12% Egg shell & Metakaolin powder with cement and 35% Washed bottom ash with fine aggregates was used. The maximum strength obtained at 7^{th} day is 4.90 N/mm^2.
6) After 14 days of curing, the maximum flexural strength obtained was 5.99 N/mm^2 for same replacements and addition.
7) After 28 days of curing, maximum flexural strength obtained was 7.12 N/mm^2.
8) In case of flexural strength, the optimum percentage that was noticed, was at replacement of 12% Egg shell & Metakaolin powder with cement and 35% Washed bottom ash with fine aggregate.
9) After 7 days of curing, the maximum tensile strength obtained was 3.95 N/mm^2 for same replacements and addition.
10) After 14 days of curing, the maximum tensile strength obtained was 4.32 N/mm^2 for same replacements and addition
11) After 28 days of curing, maximum tensile strength obtained was 5.18 N/mm^2.
12) In case of tensile strength, the optimum percentage that was noticed, was at replacement of 12% Egg shell & Metakaolin powder with cement and 35% Washed bottom ash with fine aggregate.

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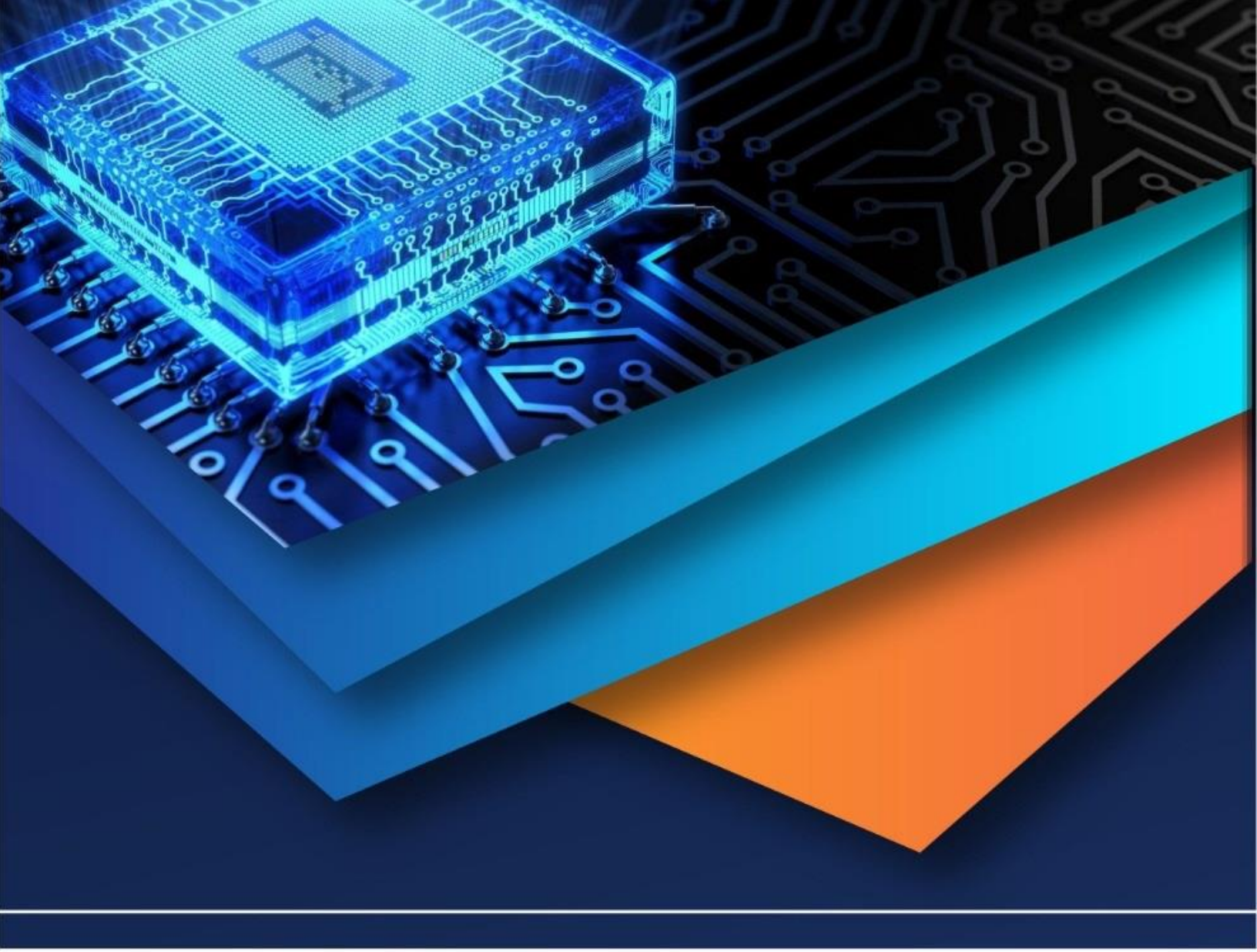

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