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Replacement of Fine Aggregate by Mixture of Ceramic and Surkhi Powder in Concrete

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***Abstract*—This paper under seeks the effect on the compressive strength and split tensile strength of concrete by partial and full replacement of fine aggregate by mixture of ceramic and surkhi powder in equal proportions. The reason for using ceramic as fine aggregates is that it is a waste material usually found in the form of broken insulators, damaged roof tiles and table ware, etc. Surkhi makes cement mortar and concrete more water proof and also more resistant to alkali and salt action as compared to those in which no surkhi is present. Thus this combination of ceramic and surkhi powder as replacement of fine aggregate not only makes the concrete mix economical but also makes it more resistant to various attacks, that too without decreasing its strength. For conducting the tests, initially a portion of conventional fine aggregate (i.e. sand) was replaced by equal proportions of ceramic and surkhi powder till all of fine aggregate got replaced. The results obtained from various tests conducted on concrete of grade M25 were analyzed and ultimately compared to that of the standard M25 grade. It was observed that with the increase in the percentage of ceramic and surkhi powder the compressive and split tensile strength of the concrete mix increased, with its maximum value for the specimen in which 80% of the fine aggregates got replaced by mixture of ceramic and surkhi powder. For the specimen in which all of conventional fine aggregate was replaced by the mixture of ceramic and surkhi powder, there was a slight decrease in the values of compressive and split tensile strength.**

Keyword*— *Compressive strength, Split cylinder test, Slump test, Water-Cement ratio.

I. INTRODUCTION

Electric ceramic insulators find their use in applications that require a nonconductive rigid element for the dissipation of heat. Ceramic electrical insulators are used in electrical equipments to support and separate electrical conductors without allowing current through them. However, it is unrealistic to expect that every insulator will last forever and never fail. Nowadays insulators have reached a high level of reliability. But still failures can and do occur due to inferior design and materials, improper manufacturing, flashover across insulator, misapplication of the insulator for its intended service, extreme stresses linked to weather, vandalism, wildlife or mishandling. Because of these failures the insulator can no longer be used and finds its worth as a waste material. Thus, its use as a fine aggregate not only serves structural purposes but also mitigates its disposal problems.

Surkhi has often been used as a substituent of sand as it imparts strength and hydraulicity to concrete. Surkhi is a pozzolanic material which also increases the water proofing ability of the concrete. It not only imparts strength to the concrete but also increases the economy of the concrete to a considerable extent. It is made by grinding burnt bricks, brick-bats, or burnt clay to powder. Surkhi not only makes the concrete water proof and resistant to alkali attack but also reduces cracking and temperature rise during hydration in a mass cement concrete. Surkhi has often been used as a substituent for fine aggregates. But in this study, it is used in combination with the ceramic powder. In order to use ceramic and surkhi mixture as fine aggregate in concrete these materials need to be grinded to obtain their powdered form. The powdered form was properly sieved passing through 4.75mm sieve. Concrete of grade M25 was prepared at a water cement ratio of 0.45 and part of its fine aggregate was replaced by ceramic-surkhi mixture in equal proportions starting from 20% (10% ceramic + 10% surkhi) in specimen S1 for compressive strength test and specimen J1 for split cylinder test. Further the percentage of ceramic-marble mixture was increased to 40% (20% ceramic + 20% surkhi) for specimen S2 and J2,60% (30% ceramic + 30% surkhi) for specimen S3 and J3,80%(40% ceramic + 40% surkhi) for specimen S4 and J4,and finally 100%(50% ceramic + 50% surkhi) for specimen S5 and J5. For conducting compressive strength test specimens were prepared in the form of cubes and in the form of cylinders for split cylinder test.

Specimens were casted in accordance with the Indian Standard Codes of practice. Specimens were prepared by hand mixing which accounted for 10% increase in the amount of cement to be used. The specimens were casted, cured and ultimately tested. Workability of concrete was measured by carrying out the slump test of fresh concrete mix. The respective tests were carried out at the age of 7 days and 28 days. Moreover, compression testing machine was (CTM) was used for carrying out compression and split cylinder tests. There was increase in compressive and tensile strength up to a certain point of increase in percentage of ceramic-surkhi mixture. The maximum value of compressive strength and tensile strength was obtained for specimen S4 and J4 respectively. However, there was decrease in slump value as the percentage of ceramic-surkhi mixture was increased to 80% i.e. slump value was minimum for specimen S4 and J4 and maximum for S1 and J1.

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II. MATERIALS USED

A. Cement

Cement is a powdery binding substance prepared by calcination of lime and clay. It is mixed with water to form mortar or mixed with sand, gravel and water to make concrete. In this study Ordinary Portland cement of grade 53 with 32% normal consistency conforming to IS: 12269-1987 was used. Initial and final setting time of cement was found to be 110 minutes and 290 minutes respectively. Specific gravity and Fineness modulus of cement was 3.14 and 2.9% respectively.

TABLE I. PROPERTIES OF CEMENT

Name of cement	Ambuja cement
Grade of cement	53 OPC
Initial setting time	110 minutes
Final setting time	290 minutes
Standard Consistency	32%
Specific Gravity	3.14
Fineness Modulus	2.9%

B. Sand

Sand is a naturally occurring granular material composed of finely divide rocks and mineral particles. It is defined by size being finer than gravel and coarser than slit. River sand locally available confirming to grading zone III of IS: 383-1970 was used in the study. The size of the particles of sand was 4.75mm and down size. Specific gravity of sand was found to be 2.605.

TABLE II. PROPERTIES OF SAND

Grading Zone	Zone III conforming to IS : 383-1970
Specific Gravity	2.605
Fineness Modulus	3.1%
Water Absorption	1%
Surface Texture	Smooth

C. Coarse aggregate

Coarse aggregate conforming to the IS: 383-1970 was used in the form of crushed angular stone. Coarse aggregate passing through the 20mm sieve and retained on 4.75mm sieve was used. For better workability, graded aggregates of 20mm and 10mm were used. Specific gravity of 20mm and 10mm aggregates was found to be 2.885 and 2.912 respectively.

Fig. 1. Gravel as a coarse aggregate

TABLE III. PROPERTIES OF COARSE AGGREGATE

Sp. Gravity of 20mm aggregates	2.885
Sp. Gravity of 10mm aggregates	2.912
Sp. Gravity of combined aggregates	2.899
Fineness Modulus	7.5
Water Absorption of 20mm aggregates	0.97%
Water Absorption of 10mm aggregates	0.83%
Water absorption of combined aggregates	0.9%
Particle shape	Angular

D. Ceramic

Ceramic materials are crystalline inorganic, non-metallic materials made from compounds of a metal and a non-metal. They are mainly composed of clay (kaolinite), formed by the action of heat and subsequent cooling. Ceramic materials are found in the form of insulators, crockery, showpieces, roof tiles, tableware, disc brakes, etc. Electric ceramic insulators find their use in applications that require a nonconductive rigid element for the dissipation of heat. Ceramic electrical insulators are used in electrical equipments to support and separate electrical conductors without allowing current through them. However, it is unrealistic to expect that every insulator will last forever and never fail. Because of these failures the insulator can no longer be used and finds its worth as a waste material. Thus, its use as a fine aggregate not only serves structural purposes but also mitigates its

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disposal problems. In this study ceramic was collected from a local grid station in the form of broken insulators. The ceramic insulators were in the form of pin and suspension insulators and thus needed to be brought to the powdered form through grinding.

Fig. 2 and 3 Ceramic waste

E. Surkhi

Surkhi is finely powdered burnt clay made from slightly under burnt bricks. It serves as a substituent for fine aggregates due to its property of being pozzolanic and when mixed with concrete makes it water proof and resistant to alkali and salt attacks. In this study, surkhi was collected from the local kiln. Surkhi has often been used as a substituent of sand as it imparts strength and hydraulicity to concrete. Surkhi is a pozzolanic material which also increases the water proofing ability of the concrete. It not only imparts strength to the concrete but also increases the economy of the concrete to a considerable extent. It is made by grinding burnt bricks, brick-bats, or burnt clay to powder. Surkhi not only makes the concrete water proof and resistant to alkali attack but also reduces cracking and temperature rise during hydration in a mass cement concrete.

Fig. 4 Surkhi powder

F. Water

Portable water was used for mixing and curing of specimens. Water used was free from suspensions and other impurities. pH value of water was within the limits as prescribed by IS: 456-2000 i.e. not less than 6. Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Generally if water is fit for drinking it is fit for making concrete. This does not appear to be a true statement for all conditions. Some waters containing a small amount of sugar are fit for drinking but not for mixing concrete and conversely water suitable for making concrete may not necessarily be fit for drinking. The pH of the water used for making concrete should be in the range of 6 and 8. Hence the water used for making concrete should be free from any impurities which may impart undesired properties to the concrete.

The content of water affects the workability of concrete. Water content in a given volume of concrete will have a significant influence on the workability. The higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete which is one of the important factors affecting workability. It should be noted that from the desired point of view, increase of water content is the last resource to be taken for improving workability even in the case of uncontrolled concrete. More water can be added, provided a corresponding higher quantity of cement is also added to keep the water/cement ratio constant, so that the strength remains the same.

III. PREPARATION OF SPECIMENS

A. Concrete mix design

Based on the above mentioned properties of these materials the required design mix of M25 was calculated based on the procedure given in IS: 10262-2009. Accordingly the final mix ratio was calculated as 1:1.56:2.26 at a water cement ratio of 0.45. The materials were weighed by making use of an electronic weighing balance. Concrete was placed in moulds in layers and tampered accordingly. The specimens cast were removed from moulds after 24 hours and kept for curing in water.

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TABLE IV. MIX DESIGN PROPORTIONING

S.No.	Mix Proportioning	Cement	Fine Aggregates			Coarse Aggregates
			Sand	*Ceramic*	*Surkhi*	
1	M1	100%	80%	10%	10%	100%
2	M2	100%	60%	20%	20%	100%
3	M3	100%	40%	30%	30%	100%
4	M4	100%	20%	40%	40%	100%
5	M5	100%	0%	50%	50%	100%

B. Mixing of concrete

Mixing of concrete is defined as the complete blending of the materials which are required for the production of a homogenous concrete. The mixing should ensure that the mass becomes homogenous, uniform in colour and consistency. In this study, specimens were prepared by hand mixing which accounted for 10% increase in the amount of cement to be used.

Hand mixing is practiced for small scale unimportant concrete works. Hand mixing should be done over an impervious concrete. Spread out the measured quantity of coarse aggregates and fine aggregates in alternate layers. Pour the cement on the top of it and mix them dry by shovel, turning the mixture over and over again until uniformity of colour is achieved. Water in small quantities should be added towards the end of the mixing to get the required consistency of the concrete. Water to be used in this method should not be poured but sprinkled.

Fig. 5. Mixing of Ingredients

C. Specimens

Specimens were prepared properly and due care was taken for their preparation. Oil was rubbed on the inner surface of the moulds before concrete was poured in them, so that it becomes easy to remove specimens from moulds without any damage. Specimens were checked for the dimensions after their curing. For each mix proportion, 3 cubes of 150mm x 150mm x 150mm size were tested to determine compressive strength of concrete and 3 cylinders of 150mm diameter and 300mm length were tested to determine split tensile strength of concrete.

Fig. 6. Casting of Specimens

D. Curing of concrete

Curing is the maintenance of satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop. Proper curing is essential for the complete attainment of the strength of the concrete specimen. All the specimens were placed in the water tank for a period of 28days.

IV. TESTING AND RESULTS OF SPECIMENS

A. Slump test

Slump test is a test that measures the workability and consistency of the fresh concrete. Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It does not measure all factors contributing to workability, nor is it always representative of the placability of the concrete. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. Quality of concrete can also be further assessed by giving a few tappings or blows by tamping rod to the base plate. This test is used to ensure uniformity for different batches of concrete. This is used to get the workability of those concretes which are neither too harsh nor too lean. The dimensions of the slump test apparatus are:

Height = 30cm
Base diameter = 10cm
Top diameter = 20cm

TABLE V. RESULTS OF SLUMP TEST

S.No.	Specimens	Slump Value in mm
1	S1 and J1	97
2	S2 and J2	63.33
3	S3 and J3	42.66
4	S4 and J4	26.33
5	S5 and J5	13.33

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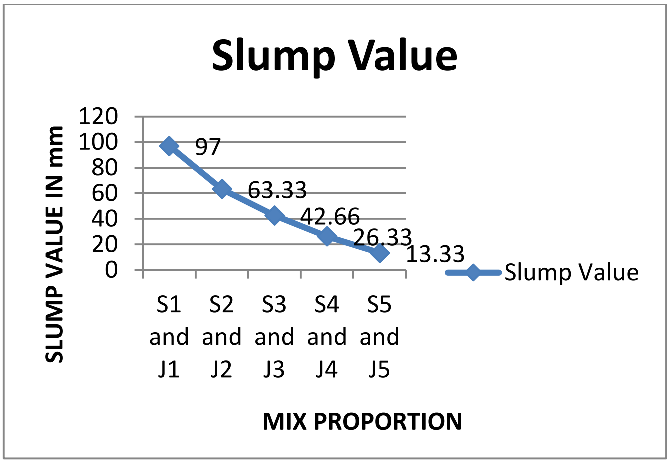

Fig. 7. Showing Variation of Slump Value

Compaction factor test was also carried out on the fresh concrete. Compaction factor test gives us idea about workability of fresh concrete. It is a more rational test than slump test i.e. it is more precise and sensitive than that of slump test. From compaction factor test we calculate compaction factor which gives us an idea about workability of concrete. More is the value of the compaction factor more is the workability of fresh concrete and vice versa. It can easily be carried on a very lean as well as a very harsh concrete.

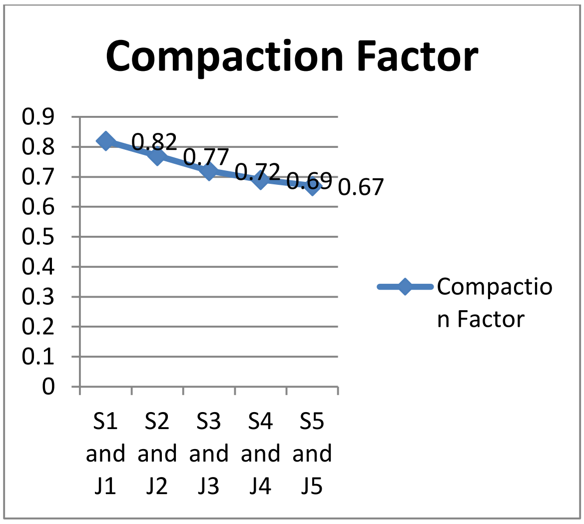

Fig. 8. Variations In Compaction Factor

From the above results, it is clear that the specimens S5 and J5 form a harsh concrete. While as, the specimens S1 and J1 form a lean concrete. The harshness of the concrete gets on increasing with increarse in the amount of ceramic-surkhi powder. Thus the specimens with higher slump value form a more workable and consistent concrete. Moreover, the mixing of such concrete becomes easier.

Fig. 9. and 10. Slump Test

B. Compressive strength test

Compressive strength is the resistance shown by the specimen to withstand loads tending to reduce size. Out of all the tests applied on the concrete, compressive strength test is of utmost importance as it gives idea about all the characteristics of concrete. The specimens were tested by compression testing machine after 7 day curing and 28 day curing with load being applied gradually. The specimens should be finished properly with no lumps and voids in it, as it will make the concrete weak. The specimens should be marked properly with date of casting encrypted on it. After proper mixing and curing of concrete, the specimens were placed in the compression testing machine with load being applied gradually. Load recorded at the failure of the specimen divided by the cross sectional area gives the compressive strength of the concrete cube. It must be noted that the mixing, curing and testing of the specimens should be done in accordance with the IS codes.

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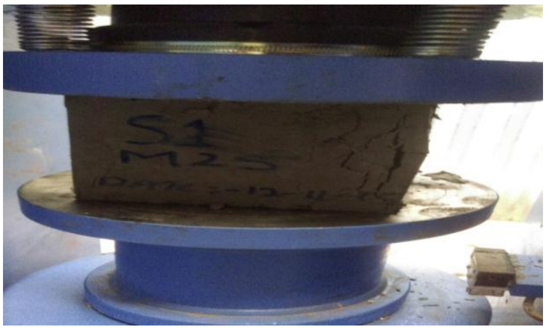

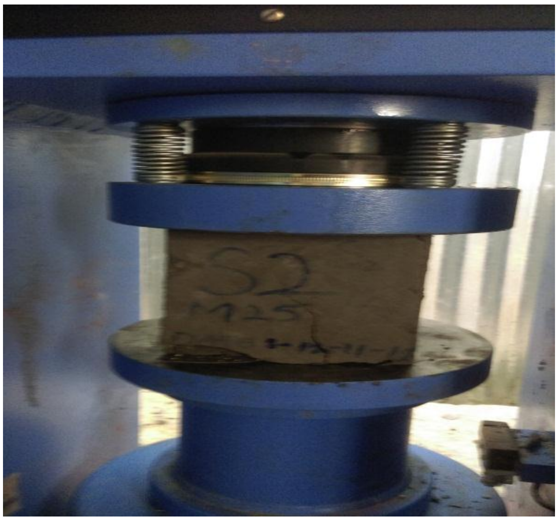

Fig. 11, 12, 13 and 14. Compression Test for Different Specimen

TABLE VI. RESULTS OF COMPRESSIVE STRENGTH TEST

S.No.	Specimen	Weight (Kg)	Compressive strength after 7days (N/mm^2)	Compressive strength after 28days (N/mm^2)
1	S1	8.045	14.67	22.88
2	S2	8.028	15.25	23.33
3	S3	8.032	18.31	28.33
4	S4	7.774	21.84	33.50
5	S5	7.825	14.59	22.22

From the above results, it is clear that the values of the compressive strength for the specimens S1, S2 and S5 are less than the conventional concrete. But for specimens S3 and S4, the values are higher. The maximum value of compressive strength was 33.50 N/mm^2 for specimen S4 with minimum value of 22.888N/mm^2 for specimen S1.

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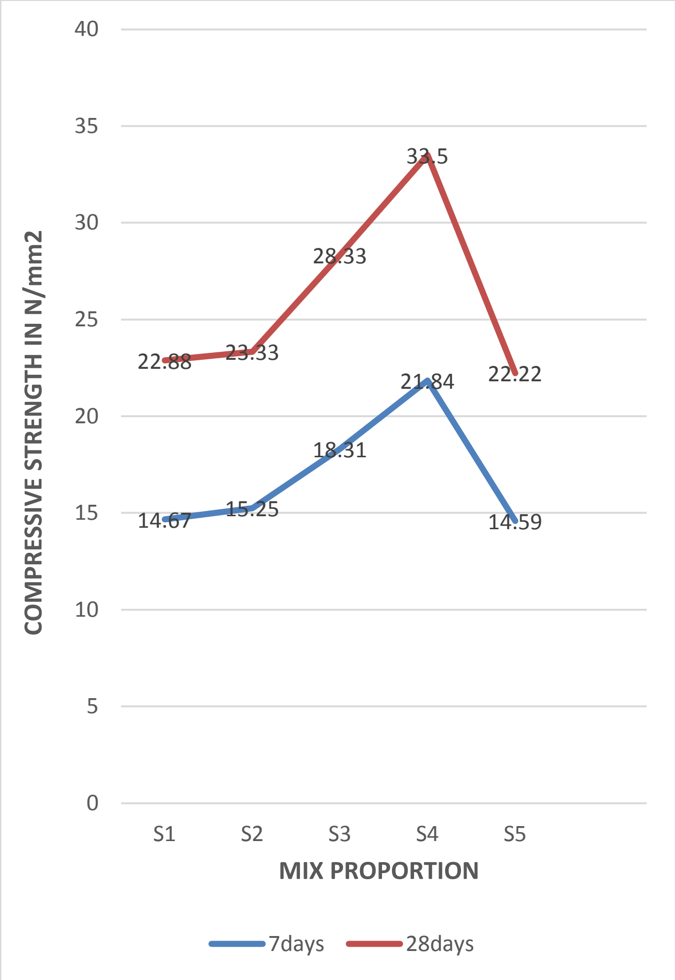


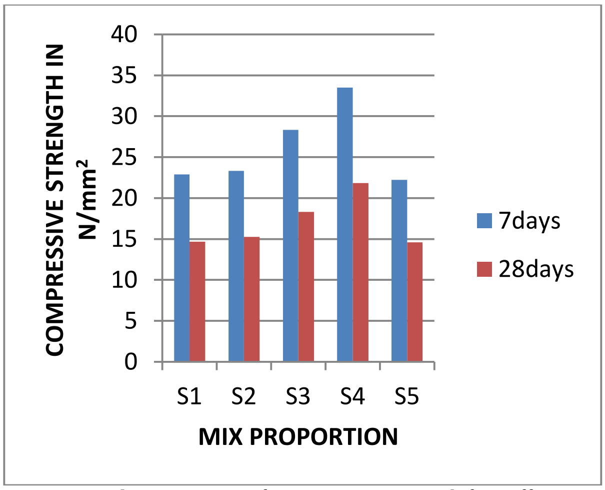
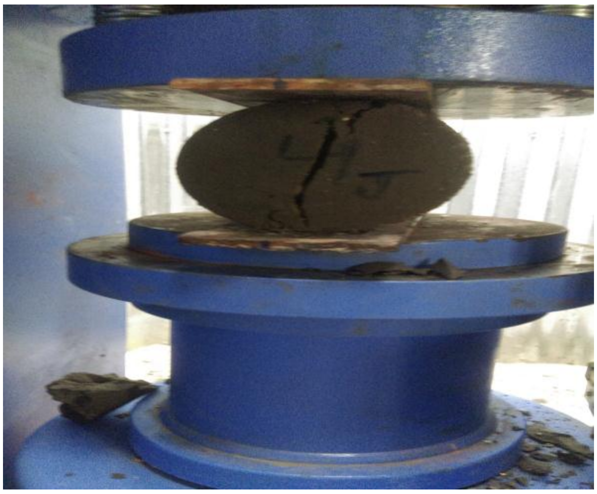


Fig. 15 and 16. Variation of Compressive Strength for Different Specimens After 7 And 28days

C. Split tensile strength test

The split tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The tests conducted for split tensile strength of concrete is done as per IS: 5816-1959. The tests were conducted on a compression testing machine after 7days and 28days curing with load being applied gradually. Load recorded at the failure was used to calculate the split tensile strength of concrete by using the formula:

Tsp=2P/pi D
Where Tsp = Split tensile strength
P = Load at failure
D= Diameter of the specimen
L= Length of the specimen



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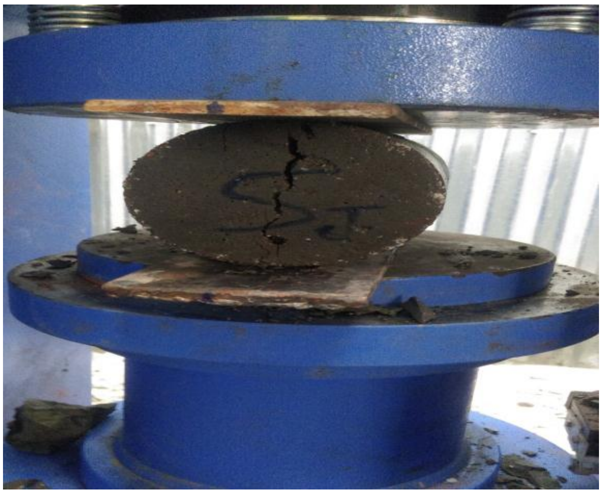
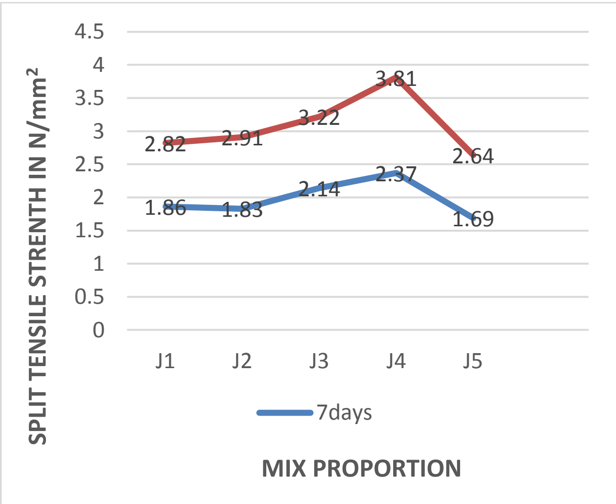


Fig. 17, 18, 19 and 20. Split Tensile Strength Test

TABLE VII. RESULTS OF SPLIT TENSILE STRENGTH TEST

S.No.	Specimen	Weight	Split tensile strength after 7days (N/mm^2)	Split tensile strength after 28days (N/mm^2)
1	J1	3.804	1.86	2.82
2	J2	3.777	1.83	2.91
3	J3	3.711	2.14	3.22
4	J4	3.743	2.37	3.81
5	J5	3.705	1.69	2.64

From the above results, it is clear that the values of split tensile strength for the specimens increases as the proportion of the ceramic-surkhi mixture is increased up to 80% with maximum value of $3.81N/mm^2$ for specimen J4.



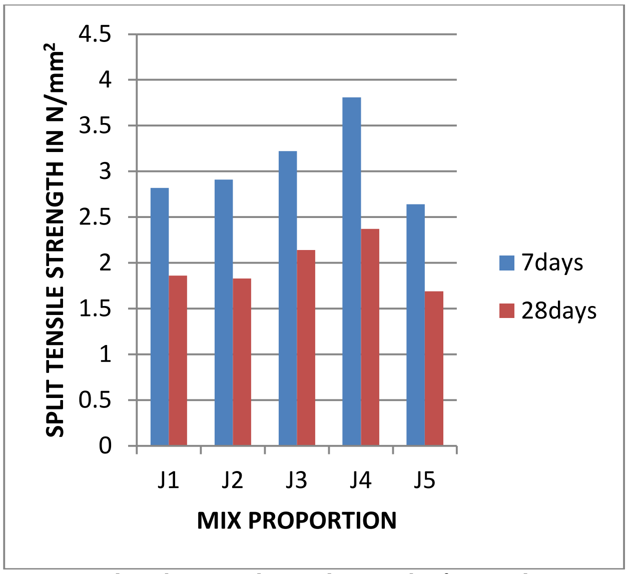


Fig. 21 and 22 Showing Split Tensile Strength After 7 And 28 Days

5. CONCLUSION

Increase in the value of strength without a considerable increase in the economy of the concrete construction has always been the main talking point of the advancements made in the field of the concrete technology. Researchers have always tried to make the concrete economical by replacing either aggregates or by making use of other pozzolanic agents. In this research paper, the fine aggregates were replaced in a definite pattern by waste materials like ceramic powder and surkhi. This replacement not only made the concrete economical but also increased its strength properties to a considerable extent with a maximum compressive and split tensile strength of $33.50N/mm^2$ and $3.81N/mm^2$ (for specimen S4 and J4) for an M25 grade of concrete. In the specimens S4 and J4, 80% of sand was replaced by mixture of ceramic and surkhi powder. In future, the use of such waste materials as fine aggregates on large scale can decrease the overall cost of the production.

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