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EXPERIMENTAL INVESTIGATION ON THE STRENGTH CHARACTERISTICS OF CONCRETE MADE WITH METAKAOLIN, FOUNDRY SAND AND DEMOLITION WASTE

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ABSTRACT

Concrete had reached its increasing demand since the construction industry involved innovation in all forms of phenomenal infrastructural works. The main objective of our project lies in find a perfect solution for the diminishing resources of cement, fine and course aggregates. Our ideology was adding metakaolin, foundry sand and demolition waste to the concrete and studying the strength properties of concrete with the variation in nominal mix. i.e., to study the strength properties of concrete (M20 Grade) for mix ratio of 5%,10%,15%,20% and 25% at 7 and 28 days.

The strength properties being studied in our theses are as follows:

1. *Compressive strength*
2. *Split Tensile strength*
3. *Flexural strength*

These properties were then compared with the nominal concrete mix.

Keywords: Metakaolin, Foundry Sand, Demolition Waste, Super plasticizer.

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1. INTRODUCTION

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension. This weakness in the concrete makes it to crack under small loads, at the tension end. Concrete is the most vital material for the construction of high rise buildings and various infrastructures. Infrastructures development in such areas particularly in developing countries like India is more concrete is a mixture of cement, fine aggregate, coarse aggregate and water. At present, the construction industry in plagued with the scarcity of tis essential constituent material of concrete and hence the replacement is made with metakaolin, foundry sand demolition waste for each additive respectively. The natural sources of river sand are getting depleted in gradually. The demand for the protection of the natural environment and the ban on mining in some area is further aggravating the problem of availability of river sand. There, in the present circumstances of scant sources of river sand and boom in infrastructure development, it becomes essential and more significant to find out its substitute material in concrete. Foundry sand obtained as on output from casting medium in blast furnaces due to its fineness modulus has been used as a replacement for river sand and metakaolin due its binding capacity and molecular structure has been used as partial additive in cement. Demolition waste available in large volume are hence crushed and sieved for 20mm aggregate size of all mortars.

2. REVIEW OF LITERATURE

Narmatha & Felixkala (2016) discussed the effects of partial replacement of cement with Metakaolin in concrete, proved the following conclusions stating that the strength of all Metakaolin concrete mixes over shoot the strength of OPC and hence the increase in Metakaolin content improved the compressive strength and split tensile strength up to 15% cement replacement, thus encouraged the use of Metakaolin, as a pozzolanic material for partial replacement in producing high performance concrete.

Sai Kumar & Krishna Rao (2014) found that concrete a composite material made from cement, water, fine aggregate and coarse aggregate. But present researchers are in interest of finding new cement materials by waste materials or waste products produced from industries which are harmful to environment. The present paper deals with partial replacement of cement with quarry dust and metakaolin which are having silica used as admixture for making concrete. First quarry dust is made partial replacement of cement and found that 25% of partial replacement is beneficial to concrete without loss of standard strength of cement. Making 25% partial replacement of cement with quarry dust as constant, 2.5%, 5.0%, 7.5%, 10.0%, 12.5% metakaolin was made in partial replacement of cement and results were found that quarry dust and metakaolin usage in partial replacement to cement can be made.

Sarita Chandrakanth & Ajay.Hamane(2016) provided the following conclusion regarding properties of concrete incorporating waste foundry sand and recycled aggregate and found that compressive strength of concrete mix increased with increase in percentage of waste foundry sand and recycled aggregate as compared to normal concrete. It was also found that split tensile strength increased with increase in percentage of waste foundry

Sand and recycled aggregate up to 40% replacement after that it reduces. Further results also proved that flexural strength increased with increase in percentage of waste foundry sand and recycled aggregate up to 40% replacement after that it reduced.

Pendhari Ankush & Demse Dhananjay (2017) summarized the conclusion based on tests conducted for various properties of concrete like strength, durability etc, and hence explained the positive as well as negative changes in the properties of concrete on the partial replacement of fine sand by waste foundry sand from the past researches and the conclusion made by us shows the positive change in the utilization of waste foundry sand in construction field. As these results gave the great potential towards the development on environment friendly and strengthen cementations concrete.

Tushar Sonawane & Sunil Pimplikar (2014) showed the use of recycled aggregate up to 30% does not affect the functional requirements of the structure as per the findings of the test results and predetermined various tests conducted on recycled aggregates and results compared with natural aggregates are satisfactory as per IS 2386. The future use of the wastes can be mentioned by the use of recycled aggregate in construction, energy & cost of transportation of natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.

Prakash Somani & Brahmtosh Dubey (2016) proved that the demolished aggregate possesses relatively lower bulk crushing, density and impact standards and higher water absorption as compared to natural aggregate and the tests conducted on demolished aggregates and results compared with natural coarse aggregates were satisfactory as per IS 2386.The major output would be that the compressive strength of demolished aggregate concrete was relatively lower up to 15% than natural aggregate concrete.

3. METHODOLOGY

Figure 1 Flow Chart Adopted for concrete making

4. MATERIALS

4.1. Cement

A cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together.

Table 1 Physical Properties of Cement

CEMENT PROPERTIES	VALUE
SPECIFIC GRAVITY	3.15
FINENSS	5% retained
SOUNDNESS	10 mm
NORMAL CONSISTENCY	32%
SETTING TIME	
INTIAL	60 min
FINAL	250 min
COMPRESSIVE STRENGTH	
3 DAY	27 N/mm2
7 DAY	37 N/mm2
28 DAY	58 N/mm2

4.2. River Sand

The locally available river sand was used as fine aggregate in the present investigation. The sand was free from clayey matter, salt and organic impurities. Aggregate that pass through a 4.75mm IS sieve and having not more than 5 percent coarser material are known as fine aggregate. Main function of fine aggregate is to fill the voids in between coarser particles and helps in producing workability and uniformity in mixture.

Table 2 Properties of River Sand

RIVER SAND PROPERTIES	VALUE
SPECIFIC GRAVITY	2.617
BULK DENSITY	
LOOSE	15 KN/m3
COMPACTED	16 KN/m3
WATER ABSORPTION	0.20%
FINESS MODULUS	2.46
GRADING	Zone-II

4.3. Coarse Aggregate

The aggregate having size more than 4.75 mm is termed as coarse aggregate. The graded coarse aggregate is described by its nominal size i.e. 40mm, 20mm, 16mm, 12.5mm etc. 80mm size is the maximum size that could be conveniently used for making concrete. They may be in the form of irregular broken stone or naturally occurring gravel.

Table 3 Properties of Coarse Aggregate

COARSE AGGREGATE PROPERTIES	VALUE
SPECIFIC GRAVITY	2.76
BULK DENSITY	
LOOSE	14 KN/m3
COMPACTED	16 KN/m3
WATER ABSORPTION	1.129
FINESS MODULUS	6.78
IMPACT VALUE	17.37%
LOS ANGELES OBRATION	21.56%

4.4. Metakaolin

Meta kaolin is not a by-product. It is obtained by the calcinations of pure or refined Kaolinite clay at a temperature between 6500 C and 8500 C, followed by grinding to achieve a finesse of 700-900 m2/kg. It is a high quality pozzolonic material, which is blended with cement to improve the durability of concrete. When used in concrete it will fill the void space between cement particles resulting in a more impermeable concrete. Metakaolin, is a relatively new material in the concrete industry, is effective in increasing strength, reducing sulphate attack and improving air-void network. Pozzolanic reactions change the microstructure of concrete and chemistry of hydration products by consuming the released calcium hydroxide (CH) and production of additional calcium silicate hydrate (C-S-H), resulting in an increased strength and reduced porosity and therefore improved durability. The formation and properties of Meta kaolin are shown in below. The specimen kept immerse in water for 7 and 28days.

Table 4 Physical Properties of Metakaolin

METAKAOLIN PROPERTIES	VALUE
SPECIFIC GRAVITY	2.1
DENSITY (gm/cm^3)	2.17
BULK DENSITY (gm/cm^3)	1.26
COLOUR	White

4.5. Foundry Sand

Most of the metal industries prefer sand casting system. In this system mould made of uniform sized, clean, high silica sand is used. After casting process foundries recycle and reuse the sand several times but after some time it is discarded from the foundries known as waste foundry sand. The application of waste foundry sand to various engineering sector can solve the problems of its disposal and harmful effect to environment. Foundry sand is clean, uniformly sized, high-quality silica sand that is bounded to form moulds for ferrous (iron and steel) and non-ferrous (copper, aluminum, brass) metals. Type of foundry sand depends on the casting process in foundries. Foundry sand is generally of two types: Green sand, chemically bounded sand. Additive in sand depends on type of metal casting. Use of waste foundry sand as full or partial replacement by fine aggregate helps to achieve different properties or behavior of concrete.

Table 5 Physical Properties of Foundry sand

FOUNDRY SAND PROPERTIES	VALUE
SPECIFIC GRAVITY	2.2
BULK DENSITY	
LOOSE	19.5 KN/m3
COMPACTED	20.5 KN/m3
WATER ABSORPTION	1.30%
FINESS MODULUS	1.6
GRADING	**Zone-II**
WATER ABSORPTION	3.10%
FINESS MODULUS	6.94
IMPACT VALUE	35%
LOS ANGELES OBRATION	37.10%
CRUSHING STRENGTH	120.50 KN

4.6. Demolition Waste

The demolished waste was transported, crushed and segregated. Several tests on segregated concretes were conducted in the laboratory such as water absorption, sieve analysis, crushing value test, impact value test, and abrasion test, workability and crushing strength of natural & demolished waste by making cubes. The demolished waste was sieved through a set of IS sieves to obtain a fitness of fine aggregate which was also replaced.

Table 6 Physical Properties of Demolition waste

DEMOLITION WASTE PROPERTIES	VALUE
SPECIFIC GRAVITY	2.47
BULK DENSITY	
LOOSE	13.1 KN/m3
COMPACTED	14.4 KN/m3

5. RESULTS

5.1. Compression Test

5.1.1. Super Plasticizer

Ceraplast 300 can be used with all types of Portland cement including blended cements and Sulphate resistant cement. Ceraplast 300 should not be pre-mixed with other admixtures. If other admixtures are to be used on concrete containing Ceraplast 300 they must be added separately. Ceraplast 300 will not have any deleterious effect on reinforcing/pre-stressing elements.

Table 7 Physical Properties of super plasticizer

SUPER PLASTICIZER PROPERTIES	VALUE
SPECIFIC GRAVITY	1.2 $\pm$ .03
COLOUR	BROWN
SUPPLY FORM	Liquid

The Compressive Strength was compared to control specimen with various percentages of Metakaolin, Foundry sand and demolition waste. The 7-day Compressive Strength varied between 19 and 21MPa. The 28-day strength varied between 24 and 26Pa. The first replacement ratio exhibited lower strengths comparatively than the other replacement percentages. The control achieved their target strength of 20MPa at 28 days whereas the replacement mixes achieved strength of more than 26MPa. The highest strength of 21MPa at 7day was achieved for the third replacement ratio and gradually decreased along 20% and 25%. This clearly shows the replacement level of 15% was the optimum Compressive Strength concerned.

Table 8 Compression test result for cubes

CUBE	MIX-NO	COMPRESSION TEST			
		7 DAY		28 DAY	
		LOAD (KN)	STRESS (N/mm²)	LOAD (KN)	STRESS (N/mm²)
1	MIX-0	460	20.46	820	36.45
2	MIX-1	455	20.35	735	32.67
3	MIX-2	470	21	830	36.89
4	MIX-3	495	22.11	860	38.22
5	MIX-4	390	17.45	780	34.67
6	MIX-5	380	16.89	690	30.68

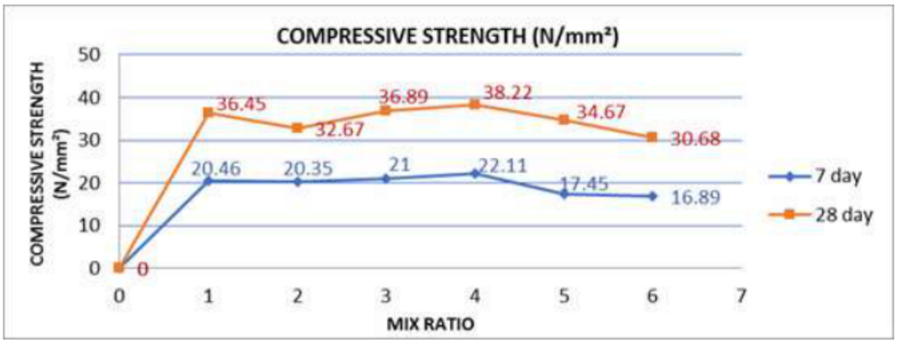

Figure 2 Compressive strength for cubes

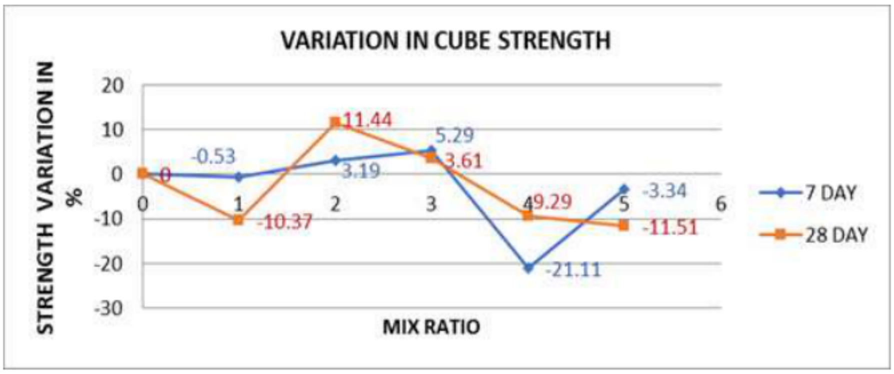

Figure 3 Variation in compressive strength for cubes

5.2. Split Tensile Test

The Split Tensile Strength was compared to control specimen with various percentages of Metakaolin, Foundry sand and demolition waste. The seven day Split Tensile Strength varied between 2.1 and 2.9MPa. The 28-day strength varied between 2.2 and 2.8Pa. The first replacement ratio exhibited higher strengths comparatively than the other replacement percentages. The control achieved their target strength of 2.97MPa at 7 days whereas the replacement mixes achieved minimum strength for 28 days. The highest strength of 2.97MPa at 7days was achieved for the third replacement ratio and gradually decreased along 20% and 25%. This clearly shows the replacement level of 15% was optimum at 7 days Split Tensile Strength of cylinder is concerned.

Table 9 Split tensile test result for cylinders

CYLINDER	MIX- NO	SPLIT TENSILE TEST			
		7 DAY		28 DAY	
		LOAD (KN)	STRESS (N/mm²)	LOAD (KN)	STRESS (N/mm²)
1	MIX-0	180	2.56	200	2.83
2	MIX-1	185	2.6	175	2.48
3	MIX-2	200	2.83	185	2.62
4	MIX-3	210	2.97	195	2.76
5	MIX-4	180	2.55	180	2.55
6	MIX-5	170	2.41	130	1.84

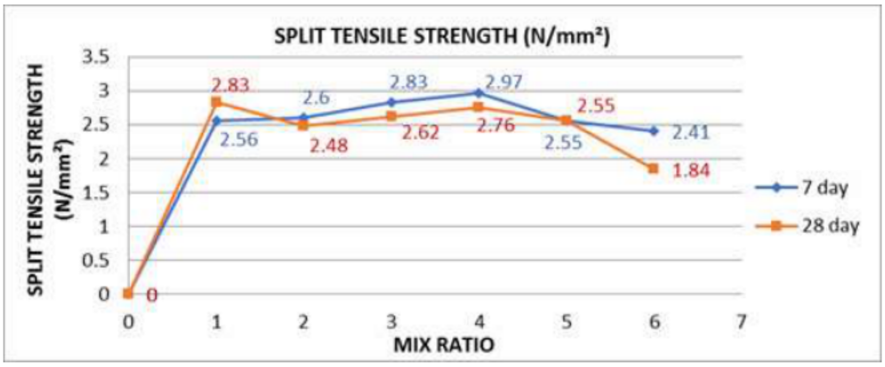

Figure 4 Split tensile strength for cylinders

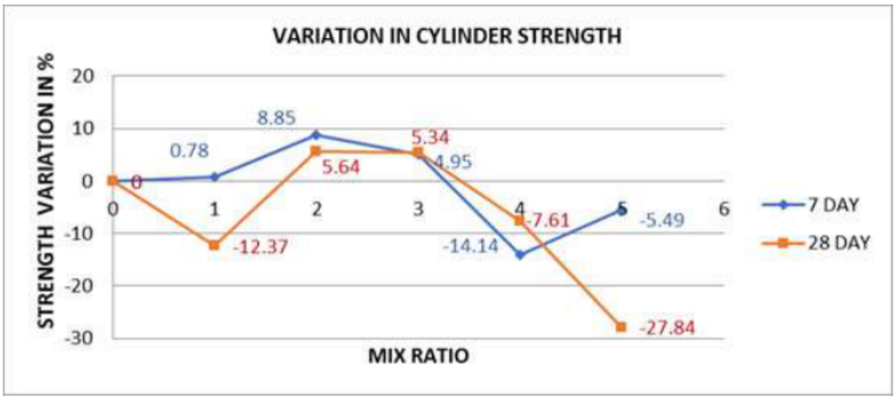

Figure 5 Variation in split tensile strength for cylinders

5.3. Flexural Test

The Flexural Strength was compared to control specimen with various percentages of Metakaolin, Foundry sand and demolition waste. The 7-day Flexural Strength varied between

4.5 and 5.9MPa. The 28-day strength varied between 3.6 and 5.8MPa. The first replacement ratio exhibited higher strengths comparatively than the other replacement percentages. The control achieved their target strength of 5.81MPa at 28 days whereas the replacement mixes achieved minimum strength for 7 days. The highest strength of 5.81MPa at 28days was achieved for the third replacement ratio and gradually decreased along 20% and 25%. This clearly shows the replacement level of 15% was optimum at 28 days Flexural Strength of cylinder is concerned.

Table 10 Flexural test result for beams

BEAM	MIX- NO	FLEXURAL TEST			
		7 DAY		28 DAY	
		LOAD (KN)	STRESS (N/mm²)	LOAD (KN)	STRESS (N/mm²)
1	MIX-0	6.4	4.73	7.4	5.55
2	MIX-1	6.1	4.28	6.6	4.95
3	MIX-2	6.2	4.58	7.05	5.29
4	MIX-3	7.7	5.58	7.75	5.81
5	MIX-4	5.95	4.39	5.85	4.49
6	MIX-5	3.95	2.96	4.85	3.64

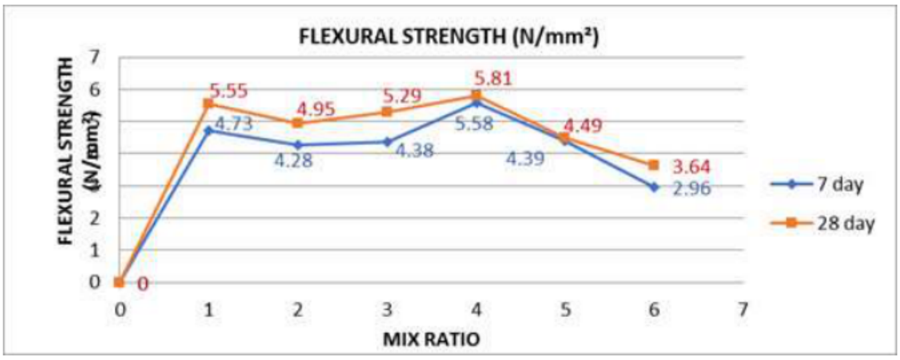

Figure 6 Flexural strength for beams

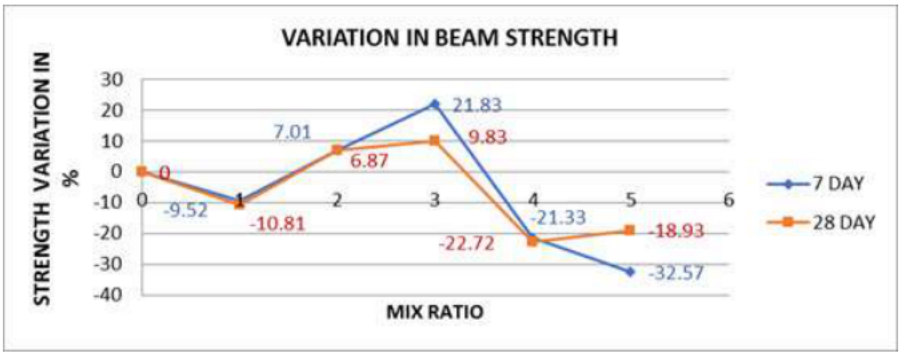

Figure 7 Variation in flexural strength for beams

6. DISCUSSION

Compressive strength is the maximum compressive stress that, under a gradually applied load, a certain solid material can carry on without fracture. Compressive strength of 7 and 28 days are shown in the Fig. 2, Fig. 4 and Fig. 6 for M-1, M-2, M-3, M-4 and M-5 replacement of the coarse aggregate by demolished concrete aggregate for M-20 mix. Three specimens for each proportion were cast and tested for comparative study. For M-3 replacement of coarse aggregate the 28 days compressive strength is 82.65% of the compressive strength of conventional concrete.

A concrete is termed as workable if it is easily placed, transported, compacted, and finished without any segregation. This property is tested by slump test. Some papers show the positive as well as negative changes in the properties. The changes in the concrete will be differing with the change in manufacturing process and resources of demolition aggregate, foundry sand and metakaolin, which can be used as a replacement for concrete. So we can make concrete effective and environment friendly. Effect of compressive, split tensile and flexural strength are studied to find the influence of waste foundry sand, demolition waste and metakaolin on plain concrete. Workability of the concrete goes on increasing with increase in the percentage of waste foundry sand. As the foundry sand contains more fine particles which increase the fineness of the concrete which results in the increase in the workability. The workability of the demolition aggregate concrete is lower than the conventional concrete because the rate of absorption of demolition aggregate is higher than nominal aggregate.

Similar results are observed in case of the effect of partial replacement of cement with Metakaolin in concrete, the strength of all Metakaolin concrete mixes over shoot the strength of OPC. 15% cement replacement by Metakaolin is superior to all other mixes. For 20% replacement moisture movement, drying shrinkage and water absorption value decreased and in the later increase of percentages it increased which shows optimum replacement gave good results in all tests as specified in codes. From the tests, the obtained value of maximum strength was 15% replacement. Further addition decreased the strength. Water absorption limit as per the codes was 10% of volume. But it was found that the addition of waste foundry sand, demolition waste and metakaolin in concrete has induced some minor variations in water absorption. However, in all the cases observed values were much less than the permissible value in the order of 12.4% of the maximum allowed value. Block density value decreased by the increase of aggregates which may be due to the reduced value of specific gravity for concrete.

7. CONCLUSION

The composition of concrete consists of Cement, Coarse and Fine aggregate which have been replaced partially by metakaolin, demolition waste and waste foundry sand, thus making the concrete mix environmentally friendly, reusable and cost effective.

The compressive strength test when carried out in a cube has seen that the optimum strength of concrete is 38.22N/mm2 which is found to be a result of replacement of nominal mix with 15% of metakaolin and 30% of Demolition aggregate and Waste foundry sand.

Split Tensile strength test when carried out with cylinder with longitudinal loading along the circumference of the cylinder it indicates an increase in strength of 2.97N/mm2 along 15% of metakaolin and 30% of demolition waste and waste foundry sand indicating the similar result to that of the compression.

The flexural strength of the beam when calculated using Universal Testing machine, the collapse is observed by means of optimum flexural strength measured as 5.81N/mm2 which also occurs along mix 3 which will be a combination of 15% metakaolin, 30% foundry sand and 30% demolition waste. Hence from the results observed the partial replacements made uniformly with respect to the calculated replacements made can provide the same or even higher strengthto that of the nominal mix for a renewable cause and cost-effective means.

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