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Study on Different Grades of Concrete for Alkaline Attack by Partially Replacing Cement with Fly Ash and Fine Aggregate with Vermiculite

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ABSTRACT: This research paper is about the investigation focuses on evaluating the strength and durability parameters of M20 and M30 grade concrete by partially replacing 20% cement with Fly Ash and fine aggregate by vermiculite with a varying percentages of 0, 5,10,15% . Workability of concrete is determined by slump cone test and compaction factor test. Mechanical properties are studied on concrete by compressive strength, flexural strength and split tensile strength. To study durability parameters the specimens are specimen are immersed into NaOH and KOH solutions for 28, 56 and 90 days by maintaining PH at 11. From the test results, it is observed that the mix having vermiculite and Fly Ash is 1.33% more workable than the mix without them. The mix having Fly Ash has 5% more strength. For durability properties at 56 days of alkaline immersion of M30 grade is found to be optimum where reduction in strength was around 9-10% compared to standard concrete having 14-16% reduction.

KEYWORDS: Mechanical properties, Fly Ash, Vermiculite, pH, NAOH and KOH.

I. INTRODUCTION

Concrete is the most widely used substance on the planet. Aggregate makes for almost 80% of the volume of concrete. The majority of normal-weight aggregates Natural stones such as Granite, Limestone, and Fine Aggregate Sand are used to make concrete. Regular materials like pumice or scoria, as well as prepared aggregates such expanded clays, shale, slates, and slags, can be used as light weight aggregate in concrete..

When volcanic rock is heated to extremely high temperatures, vermiculite is formed. It is a granular expanded aggregate with large air gaps that produces a lighter structure and sound insulating qualities when blended with an appropriate binder. It is a naturally occurring substance that is generated when mica disintegrates. It's a micaceous mineral that swells about 100 times its original size.

Vermiculite concrete represents a unique and versatile construction material that has gained popularity for its lightweight and insulating properties. The key component of vermiculite concrete is vermiculite, a natural mineral that undergoes expansion when heated, resulting in a lightweight and highly insulating aggregate. This expansion is a consequence of the mineral's water content turning into steam, causing the vermiculite particles to expand into a popcorn-like structure. This expanded vermiculite is then combined with cement and other additives to create vermiculite concrete.

II. NEED OF STUDY

The key reasons that necessitate the need of study are the limited study on incorporation of vermiculite into different grades of concrete, a light weight concrete can be produced since it is a light material and depleting of natural resources can be avoided since it can be used as a replacement to fine aggregate.

III. OBJECTIVES OF PRESENT STUDY

- To study the Compressive strength, Flexural strength and Split tensile strength for M20 and M30 grade concrete after 28days,56 days and 90 days when the mix has 0% fly ash and fine aggregate is replaced with vermiculite for varying proportions of 0, 5, 10, 15%.
- To study the Compressive strength, Flexural strength and Split tensile for M20 and M30 grade concrete after 28days,56 days and 90 days when cement is replaced with fly ash by 20% and fine

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aggregate with vermiculite for varying proportions of 0, 5, 10, 15%.

- To determine durability of concrete by immersing them into alkaline solutions of NaOH and KOH solutions for a period of 28 days, 56 days and 90 days.

IV. SCOPE OF STUDY

In the present paper the concrete specimens of M20 and M30 are casted and their mechanical properties are studied in terms of compressive strength, flexural strength and split tensile strength after specified periods of 28,56,90 days and durability parameters are studied in terms compressive strength after alkaline immersion into NaOH and KOH solutions .

V. MATERIALS

The materials used in this research include

Cement: KCP Cement of grade 53 was used for composition of concrete mix.

Sand (Fine aggregate): Aggregate Fines Commercially accessible yellow sand was used as fine aggregate in the manufacture of the concrete mix. According to IS: 10262-2019 [14] requirements, the sand is of Grade II

Coarse aggregate: angular crushed stone, available for purchase the design of the concrete mix was based on the nominal size and proportion of coarse particles that were passing through 20 mm and retained on 10 mm sieve.

Fly ash: A heterogeneous by-product of the combustion of coal in power plants is a material known as fly ash. It is a thin, grey powder that rises with flue gases and contains glassy, spherical particles. due to the pozzolanic elements included in fly ash, which interact with lime to produce cementing materials.

Water: Water is an essential component of concrete, and it chemically reacts with cement. The water used in concrete should be devoid of acid, dust, and other impurities. The PH value should be between 6 and 8.

Vermiculite: Vermiculite is a phyllosilicate mineral. A lower density for the same strength level reduces self-weight. It has a high silica concentration, which gives it a strong constraint for substituting sand and is effective for bonding and covering voids. It is generally platelets with diameters ranging from 0.04 to 4mm.

VI. SPECIMEN FABRICATION

Design Concrete mix of grade M20 and M30 asserting to IS: 10262-2019 was adopted for the formation of test specimens. The fraction of various elements of the concrete mix are given below The cement: fine aggregate: coarse aggregate and water ratio are estimated at 1: 2.36: 2.77:0.52 for M20 Grade and 1: 2.15: 2.53:0.48 for M30 grade concrete.

VII. TESTING PROCEDURE

Total 72 beams ,72 cylinders and 144 cylinders have been casted for each mix. concrete cubes of 100x100x100 mm tested for twenty eight, fifty six and ninety days' compressive strength as per IS: 516 [11], 100x100x500 mm prism tested for flexure as per IS 516 [11] and 150mmdiameter with300mm height cylinder for split tensile strength as per IS 5816 [15] [13] for different proportions of cement replaced with Fly Ash along with fine aggregates replaced with variation of 0,5,10,15% replacement of fine aggregate with vermiculite. The findings were graphed, and then comparative analysis graphs were made to indicate the effect of vermiculite on the flexural strength and split tensile strength and compressive strength of concrete at 28,56,90 days and durability in terms is studied by immersing the cubes into alkaline solutions of NaoH and KOH solutions for 28,56 and 90 days.

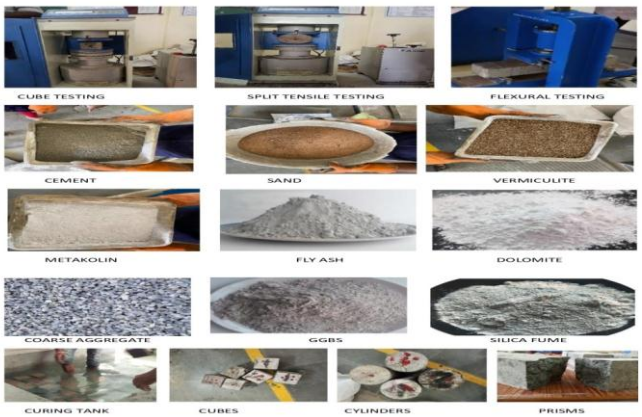

Figure-1 Materials, Specimen and Testing

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VIII. RESULTS AND DISCUSSIONS

The results of the experiment are discussed below as follows

i.Compaction Factor Test

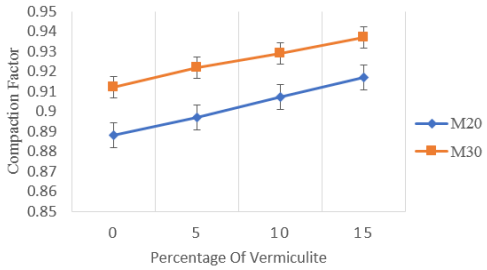

Figure-2 Compaction Factors without Fly Ash

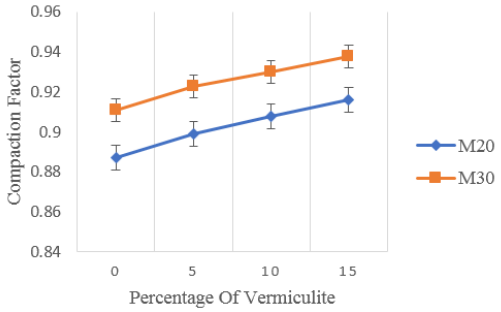

Figure-3 Compaction Factors with Fly Ash

The results of compaction factor test for the various concrete mixtures are presented above, it was observed that the compaction factor values of different percentages of vermiculite with 20% incorporation of Fly Ash was more compared to the compaction factor values of conventional concrete. High compaction factors indicate the good workability of concrete.

ii .Slump Cone Test

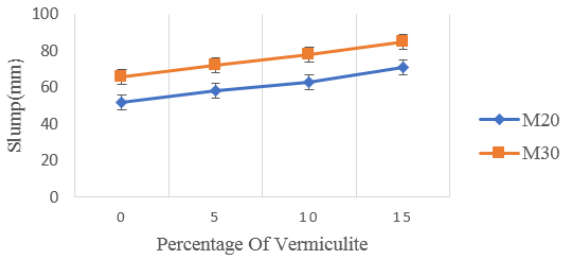

Figure-3 Variation in Slump without Fly Ash

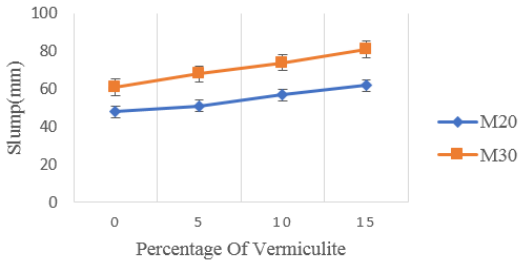

Figure-4 Variation in Slump with Fly Ash

The results of slump cone test for the various concrete mixtures are presented above, based on results, it was observed that slump values of different percentages of vermiculite and with 20% incorporation of Fly Ash was less than the slump value of the concrete mix containing different percentages of vermiculite without Fly Ash. Higher slump values indicate the good workability of concrete.

iii.Flexural Strength

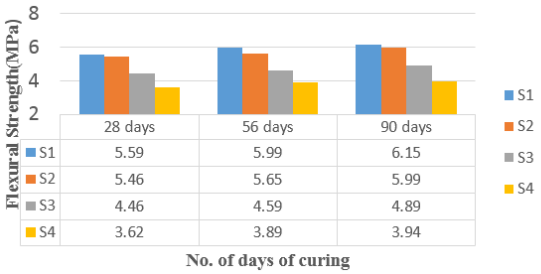

Figure-5 Flexural strength of M20 grade without Fly Ash

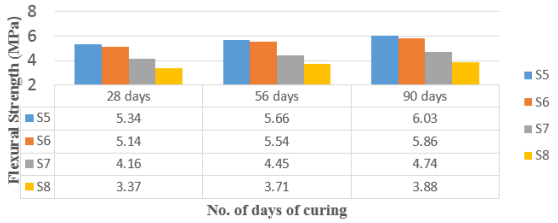

Figure-6 Flexural strength of M20 grade with Fly Ash

From the results of the Flexural strength of the vermiculite concrete with and without the addition of mineral admixture fly ash, the following observations are made

•From the above results, it was observed that Flexural strength of concrete was reducing gradually as the percentage of vermiculite was increased.

•With the addition of vermiculite, a reduction of around 2.5% is observed in all the durations of curing.

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•Reduction in Flexural strength is observed for 28 days of curing and with addition of Fly Ash indicating reduced gain of strength in presence of Fly Ash.
•Gradual gain in strength is observed after 56 days of curing.
•At 90 days of curing, the strength parameters were higher as compared to standard case for the mix with Fly Ash indicating gain of strength over a period of time.
•Final gain in strength after 56 days was found to be 5.6% more than that of samples after 28 days of curing and around 6.15% gain is observed from 56 days to 90 days.

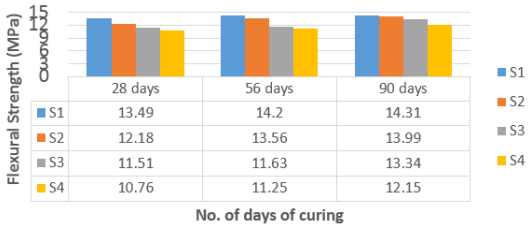

Figure-7 Flexural strength of M30 grade without Fly Ash

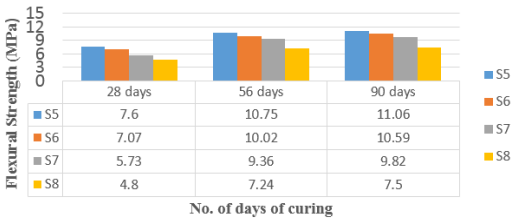

Figure-8 Flexural strength of M30 grade with Fly Ash

From the results of the Flexural strength of the vermiculite concrete with and without the addition of mineral admixture fly ash, the following observations are made
•From the above results, it was observed that Flexural strength of concrete was reducing gradually as the percentage of vermiculite was increased.
•With the addition of vermiculite, a reduction of around 4% is observed in all the durations of curing.
•Reduction in Flexural strength is observed for 28 days of curing and with addition of Fly Ash indicating reduced gain of strength in presence of Fly Ash.
•Final gain in strength after 56 days was found to be 29% more than that of samples after 28 days of curing and around 3% gain is observed from 56 days to 90 days.
•Rapid gain of strength was observed after 56 days of curing which indicates, formation of dense microstructure and the pozzolanic reaction between Fly Ash and calcium hydroxide producing C-S-H gel over the period of time.

iii.Split Tensile Strength

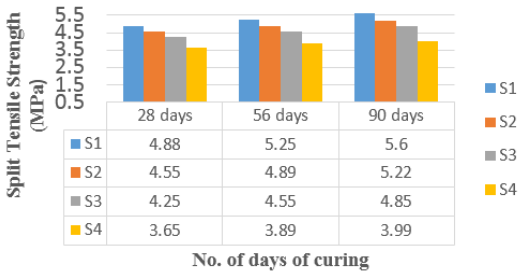

Figure-9 Split Tensile strength of M30 grade without Fly Ash

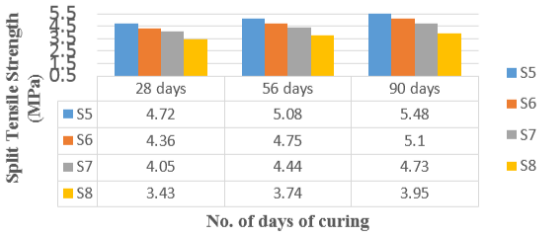

Figure-10 Split Tensile strength of M30 grade with Fly Ash

From the results of the Split Tensile strength of the vermiculite concrete with and without the addition of mineral admixture fly ash, the following observations are made

- From the above results, it was observed that Split Tensile strength of concrete was reducing gradually as the percentage of vermiculite was increased.
- With the addition of vermiculite, a reduction of around 4% is observed in all the durations of curing.
- Reduction in Flexural strength is observed for 28 days of curing and with addition of Fly Ash indicating reduced gain of strength in presence of Fly Ash.
- Final gain in strength after 56 days was found to be 8% more than that of samples after 28 days of curing and around 6.8% gain is observed from 56 days to 90 days.
- Rapid gain of strength was observed after 56 days of curing which indicates, formation of dense microstructure and the pozzolanic reaction between

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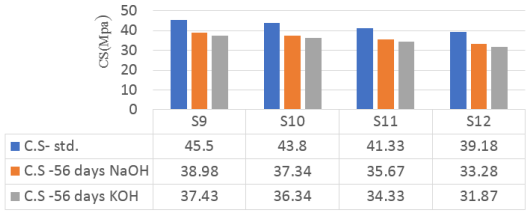
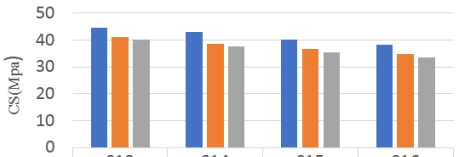
Fly Ash and calcium hydroxide producing C-S-H gel over the period of time.

iv. Compressive Strength



	S9	S10	S11	S12
C.S- std.	45.5	43.8	41.33	39.18
C.S -56 days NaOH	38.98	37.34	35.67	33.28
C.S -56 days KOH	37.43	36.34	34.33	31.87

Figure-11 56 days compressive strength of M30 grade without Fly Ash



	S13	S14	S15	S16
C.S- std.	44.63	42.9	40.23	38.3
C.S -56 days NaOH	41.06	38.61	36.7	34.78
C.S -56 days KOH	40.17	37.75	35.4	33.7

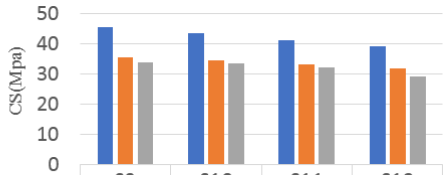
Figure-12 56 days compressive strength of M30 grade with Fly Ash

The results of compressive strengths for M30 grade concrete with different percentages of vermiculite and 20 % Fly Ash with 56 days of alkaline curing are presented above. Following observations were made

•The loss in compressive strength after 56 days of curing in alkaline solutions was around 14% for NaOH and 17 % for KOH. Further, with addition of vermiculite upto 10% the loss was around 13-14% for both the solutions.

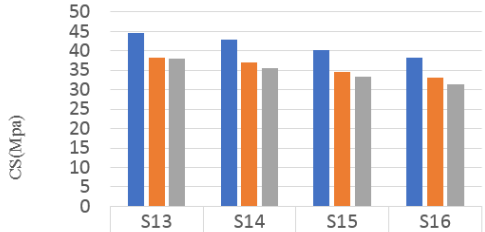
•When the percentage of vermiculite was increased to 15% it was observed that the strength reduction was around 15% for both the solutions.

•Loss in compressive strength was observed even with addition of vermiculite and Fly Ash.



	S9	S10	S11	S12
C.S- std.	45.5	43.8	41.33	39.18
C.S -90 days NaOH	35.65	34.77	33.23	31.86
C.S -90 days KOH	34.13	33.69	32.45	29.29

Figure-13 90 days compressive strength of M30 grade without Fly Ash



	S13	S14	S15	S16
C.S- std.	44.63	42.9	40.23	38.3
C.S -90 days NaOH	38.2	36.97	34.6	33.05
C.S -90 days KOH	37.93	35.61	33.39	31.41

Figure-14 90 days compressive strength of M30 grade with Fly Ash

The results of compressive strengths for M30 grade concrete with different percentages of vermiculite and 20 % Fly Ash with 90 days of alkaline curing are presented above.

•It was observed that the loss in compressive strength after 90 days of curing in alkaline solutions was around 22% for NaOH and 25 % for KOH.

•Further, with addition of vermiculite, it was observed that the percentage loss in compressive strength was 21%,19%,18% respectively for 5,10,15% of vermiculite for NaOH. But in case of KOH the loss in compressive strengths was 23%,21%,25% for 5,10,15% of vermiculite.

•A strong deterioration was observed after 90 days curing in KOH solution, the specimen could not even reach characteristic compressive strength.

•When Fly Ash was added to the mix the loss in compressive strength was observed was 14-4%,13.9,13.7,13.4% for 5,10,15% of vermiculite for NaOH curing and the percentage loss in compressive strength was increasing from 15 -17% as percentage of vermiculite was increasing.

•When Fly Ash was added the specimen could reach the characteristic compressive strength. Acceptable results were obtained in case of NaOH and a strong deterioration is observed for KOH solution for 90 days of curing in alkaline solution.

CONCLUSIONS

- In this study, the effects of replacing 20% of cement by fly ash and 5%, 10%, 15% of fine aggregate by vermiculite for concrete subjected to elevated temperature were investigated. Based on the experimental results obtained, the following conclusions can be drawn:
- Using 20% Fly ash as replacement to cement in the Vermiculite concrete the strength properties increase only marginally about 7-8%. It gives

economy in the cement consumption in addition to better durability properties.

- The Mechanical Properties-Split tensile strength, Flexural strength and compressive strength of concrete are low in early stages for mix with Fly Ash in it but the parameters are marginally increasing in the later stages in the range of 10-12%.
- It is observed that in general, by exposing the specimens to alkaline environment, the compressive strength of vermiculite concrete has increased at 28 days about 15-18% compared to conventional concrete (without vermiculite). At 56 days the strength is slightly reduced when compared to 28 days and at 90 days, the strengths are further reduced. Hence 28 days may be taken as the optimum curing period for M20 concrete.
- When the specimens with varying percentage of Vermiculite were exposed to alkaline environment, it is observed that 5% Vermiculite used as replacement to Fine Aggregate in the mix has given higher strengths at 28 days and 56 days compared to standard concrete.
- Concrete specimens containing 5% vermiculite exhibit resistance to alkaline environment compared to other concrete specimens, their damage degree was the lowest.
- It is observed that Vermiculite replacement of fine aggregate is helpful in generating higher strengths in lower grade mixes like M20 and M30. In case of higher-grade mixes
- 7.Vermiculite is not effective due to its weak structure. The weakness primarily arises from the layered structure and the presence of water molecules and exchangeable cations between the layers.
- 8.On the whole, combination of Fly Ash and Vermiculite in the concrete mixes is helpful in resisting alkaline environment without losing the strength. This is valid particularly in case of lower grade mixes M20 and M30.
- Overall, in RCC structures, Model-2 (Equilateral Plan) demonstrates an average improvement in Overturning Moment approximately **10.0%** compared to other models. For composite structures, Model-4 (Hexagonal Plan) shows an average approximately **10.33%** across all structures, indicating better performance in minimizing Overturning Moment.
- Overall, in RCC structures, Model-2 (Equilateral Plan) demonstrates an average improvement in Time Period approximately **3.16%** compared to other models. For composite structures, Model-4 Hexagonal shows an average approximately **8.45%** across all structures, indicating better performance in minimizing Time Period.

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