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Effect of Exfoliated Vermiculite as Fine Aggregate Replacement on Properties of Lightweight Concrete

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Abstract : The study investigated the use of exfoliated vermiculite as a partial replacement for fine aggregate in the production of lightweight concrete. Fine aggregate was partially replaced with exfoliated vermiculite at volumes of 0%, 50%, and 100%,. Compressive strength of the resulting concrete was tested at 7, 14, and 28 days. The results revealed a decrease in the density of the concrete with an increase in the content of exfoliated vermiculite, indicating the production of lightweight concrete. However, the compressive strength of the concrete decreased with an increase in the content of exfoliated vermiculite. It was observed that when 50% of fine aggregate was replaced with exfoliated vermiculite the compressive strength is better than 100% vermiculite concrete.

***IndexTerms* – Lightweight concrete, Compressive strength, Slump.**

1.INTRODUCTION

Certainly! In India, the traditional method of producing concrete involves excavating natural sand from riverbeds. However, this practice has led to environmental concerns and has resulted in restrictions on sand excavation imposed by the government. As a result, there is a shortage of natural sand, and the cost of sand has increased significantly. This has led to a need to find alternative sources of sand to maintain ecological balance.

One solution to the problem of sand scarcity is the use of manufactured sand, also known as M sand. M sand is a type of sand that is obtained by crushing rocks, as opposed to the traditional method of extracting sand from riverbeds. This process not only reduces the impact on the environment caused by sand excavation but also ensures a consistent quality of sand for use in construction.

The use of M sand in concrete has become increasingly popular in India due to the scarcity of natural sand. It is a cost-effective and environmentally friendly alternative to traditional sand. M sand is available in various grades, and it can be used in a range of applications, from plastering and concrete to bricklaying and paving.

The properties of M sand, such as its particle size, shape, and texture, are comparable to those of natural sand. It can be used in the same proportion as natural sand in concrete mixtures, and it offers similar strength and durability properties.

In conclusion, the use of manufactured sand as an alternative to natural sand is a viable solution to the problem of sand scarcity in India. Its production process is eco-friendly, and it offers a consistent quality of sand for use in construction. The use of M sand can help to maintain ecological balance and reduce the environmental impact caused by sand excavation.

Concrete is a widely used construction material with several benefits. In the mid-twentieth century, lightweight concrete (LWC) gained popularity in the construction industry due to its numerous advantages. LWC is used in long span bridges, high rise frames, offshore structures, etc. because of its low self-weight, higher strength/weight ratio, cost-effectiveness, superior durability, better tensile strain capacity, low thermal expansion, better heat and sound insulation properties, and enhanced fire resistance. According to ACI 213R-03, the density of structural LWC should range from 1120 to 1920 kg/m3, and its compressive strength should be over 17 MPa. Researchers are now focusing on producing high-strength sustainable LWC. In this project, vermiculite, a lightweight aggregate, was used.

II. LITERATURE REVIEW

Shanmugapriya and Uma (2012) conducted a study on the optimization of partial replacement of manufactured sand (M-sand) with natural sand using silica fume in high performance concrete (HPC). In their research, ordinary Portland cement was partially replaced with silica fume at 1.5%, 2.5%, and 5%, and natural sand was replaced with M-sand at proportions of 10%, 30%, 50%, and 70%. Compressive and flexural strength tests were performed on the concrete mixes. The results showed that increasing the percentage of M-sand led to an increase in compressive strength by nearly 20% and flexural strength by 15% in HPC. Up to 50% replacement of sand with M-sand resulted in comparable strength to the control mix. However, further increases in the percentage of M-sand caused a reduction in strength. The researchers concluded that the optimal percentage of replacement of natural sand with M-sand is 50%. Additionally, increasing the percentage of partial replacement of silica fume also increased the compressive and flexural strength of HPC [1].

In a study conducted by Nadimalla et al. (2020), the potential of M-sand as a substitute for river sand in concrete was investigated. Different replacement levels of M-sand, ranging from 0% to 100%, were used in the concrete mix designed according to IS standards. A mix ratio of 1:2.32:2.82 (M20) was considered in this research. Test specimens were casted and cured for 7 days, 28 days, and 90 days. The performance of M-sand was evaluated through various experiments including slump test, impact strength test, flexural strength, and compressive strength test. The results revealed that as the percentage of M-sand increased, the slump value decreased. Moreover, the flexural strength, compressive strength, and impact resistance of concrete were found to be higher at 100% and 50% replacement levels of M-sand with river sand, at all curing durations [2].

According to a study conducted by A. V. V. Sairam, (2017), concrete is a widely used building material due to its strength and durability. However, the constant depletion of natural sand and increasing temperatures in many regions of the world have led to the partial replacement of fine aggregate with vermiculite. This replacement can improve the concrete's resistance to shrinkage, cracking, and fire, while also reducing costs and environmental impact. To investigate the mechanical properties of M35 grade concrete, the study used different percentages (ranging from 5% to 30%) of vermiculite to partially replace fine aggregate. The mixtures also included mineral admixtures such as Fly ash and silica fume. The study found that optimal strengths were achieved with 10% silica fume added and 15% fly ash replacement by weight of cement for compressive strength and 10% silica fume added and 10% fly ash replacement by weight of cement for split tensile strength. Throughout the study, the water-cement ratio was maintained at a constant of 0.42 for all the mixtures. The study concludes that the use of vermiculite in concrete has several benefits and could be a promising alternative to natural sand in the future [3].

B. M. Preethi, P. Ashveen Kumar, and M. Hamraj conducted a study in 2021 that aimed to improve the performance of M30 grade concrete by partially replacing fine aggregate with vermiculite at varying percentages (0%, 5%, 10%, 15%, 20%, and 25%) and adding 10% constant silica fume to cement. The study also examined the effect of acid exposure on the strength and weight of concrete through experimentation. The researchers casted 12 concrete cubes of different mixes and exposed them to sulphuric acid of pH=3. The concrete cubes were 100mm x 100mm x 100mm in size and were immersed in water for 28 days before being subjected to immersion and spraying with 4% concentrated sulphuric acid for 7 days. The study found that the vermiculite-replaced concrete had an insignificant decrease in density and split tensile strength compared to normal concrete, and the addition of silica fume improved the concrete's resistance to acid exposure [4].

In 2017, Sangeetha conducted a study on the mechanical properties of dolomite and vermiculite in concrete. One solution to the problem of insufficient fine aggregate in concrete is to use vermiculite. To test this, dolomite was substituted at 10% and 15% of the weight of cement, while vermiculite was substituted at 20% and 30% of the weight of fine aggregate. A design mix of M30 was created according to IS codes, and the compressive and split tensile strengths of the concrete were measured at 7, 14, and 28 days. The results were then compared to those of conventional concrete. The study found that the optimal replacement percentages for dolomite and vermiculite were 15% and 20%, respectively [5].

In 2018, Mo et al. conducted a study to evaluate the properties of cement mortars containing expanded vermiculite as a partial replacement for sand. The study found that when expanded vermiculite was included at replacement levels of 30% and 60%, the flow diameter of the mortar increased compared to plain mortar without expanded vermiculite. This can be attributed to the porous lightweight nature of expanded vermiculite. However, the inclusion of expanded vermiculite also led to a reduction in the unit weight and compressive strength of the mortars, as well as increased water absorption. The study also observed that although weight loss of the expanded vermiculite mortars subjected to elevated temperatures increased, the expanded vermiculite had a positive effect in providing heat resistance and thermal stability to the mortars. This was evident from the reduction in compressive strength loss of the mortars upon exposure to elevated temperatures[6].

In 2023, Çelik investigated the effects of replacing cement with ground raw vermiculite (RV) on self-compacting mortar (SCM). Four different percentages of RV, namely 5%, 10%, 15%, and 20%, were used in the SCM mixtures. The study evaluated the fresh concrete properties of the SCM mixes, such as slump-flow and V-funnel times. The strength activity index test was conducted to determine the pozzolanic activity of fly ash and ground raw vermiculite. Prism specimens of dimensions 40 × 40 × 160 mm^3 were produced to measure the mechanical properties of the SCM mixtures. These samples were subjected to flexural strength tests at 7, 28, and 90 days, and compressive strength tests were carried out on the parts obtained from the flexural tests. The study also evaluated the durability properties of SCM mixes, such as capillary water absorption, sorptivity, and porosity. The fresh concrete, mechanical, and durability results of RV replacement mortars were compared to those of Class C fly ash (FA), which is commonly used in SCM mixtures. The findings revealed that the presence of 5% RV yielded the highest compressive strength value at all ages. The use of 5% and 10% RV improved the 90-day compressive strength value by 3.68% and 2.91%, respectively, compared to the FA substituted series at the same rate. The lowest sorptivity coefficient of 90 days was calculated in the RV5 series with 0.037 $mm/min^{1/2}$. The study concluded that adding 10-15% ground RV to SCM mixtures did not adversely affect their mechanical and durability properties. However, using 20% RV negatively impacted the properties of SCM [7].

Based on the literature review, it has been observed that vermiculite has been used as a replacement for fine aggregate in concrete composites at percentages ranging from 0 to 30%. However, this study aims to investigate the effect of vermiculite on concrete properties when used as a replacement for fine aggregate at higher percentages, specifically 50% to 100%. By evaluating the fresh and hardened properties of the resulting concrete, this study aims to provide further insight into the use of vermiculite as a partial replacement for fine aggregate in concrete production.

III. OBJECTIVES

The objectives of the study were fourfold. Firstly, to determine the physical properties of aggregates. Secondly, to investigate the fresh properties of lightweight concrete. Thirdly, to determine the mechanical properties of lightweight concrete. And fourthly, to identify the optimal combination of materials to develop lightweight concrete.

IV. METHODOLOGY

Concrete is a widely used building material that consists of chemically inert mineral aggregates such as fine and coarse aggregate, cement, and water. In this particular study, M-Sand and Vermiculite were used as fine aggregates in concrete in varying proportions. The M-Sand was replaced by Vermiculite at two different levels: 50% and 100%. M-Sand is an artificial sand obtained by crushing rocks or granite. The concrete used in this study was of M15 grade with a proportion of 1:1.73:3.397 for M-Sand and 1:0.92:3.397 for Vermiculite. Cubic specimens were cast and placed in a curing tank for 7, 14, and 28 days. The workability of the concrete was determined through a slump test, while the hardened properties were determined by conducting compressive strength tests on the specimens after the curing period.

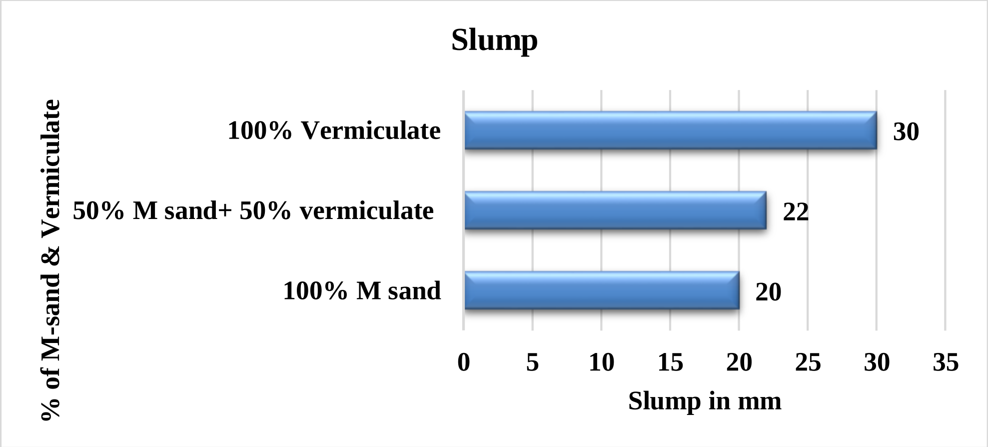

Figure 1: Slump

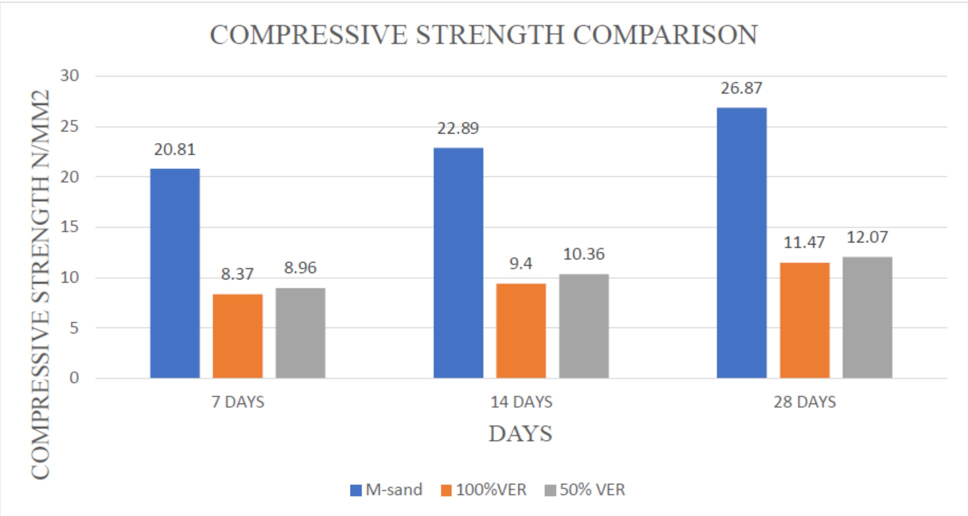

Figure 2: Compressive strength

IV. RESULTS AND DISCUSSION

This study was conducted to evaluate the effect of using vermiculate as the partial replacement of fine aggregate (50% and 100%) in concrete composites. The fresh and hardened properties of concrete were investigated on the M-sand and Vermiculite concrete and the results were observed. The slump of the concrete increased with the addition of vermiculate as it is observed Figure 1. The Compressive strength (cubes) of concrete for 7,14 and 28 days is presented in Figure 2. The result that we found for M15after 7 days of curing was 20.81 N/mm2 (M-sand concrete), 8.96 N/mm2 (50% vermiculite) and 8.37 N/mm2 (100% vermiculite), after 14 days of curing was 22.89 N/mm2 (M-sand concrete), 10.36 N/mm2 (50% vermiculite) and 9.40 N/mm2 (100% vermiculite) and after 28 days of curing was 26.87 N/mm2 (M-sand concrete), 12.51 N/mm2 (50% vermiculite) and 11.47 N/mm2 (100% vermiculite)). It is noted that strength decreases with increase in percentage of vermiculite. With the results obtained we concluded that, replacement of fine aggregate by vermiculate is preferred where concrete of less compressive strength is required. The relative density was found to be range from 1800kg/m3 to 1900kg/m3, which is less that M-sand concrete density that is 2400kg/m3 due lightweight aggregate.

V.CONCLUSION

The study concluded that the use of vermiculite as a partial replacement for fine aggregate in concrete composites leads to a decrease in compressive strength with an increase in the percentage of vermiculite used. Additionally, the resulting concrete has a relative density ranging from 1800kg/m3 to 1900kg/m3, which is less than that of M-sand concrete due to the use of lightweight vermiculite.

However, the achieved optimum compressive strength of lightweight aggregate concrete was found to be 11.47N/mm2, which is still considered a low strength concrete when compared to M-sand concrete's characteristic strength. The study also suggests that lightweight aggregate concrete can be effectively used in applications such as tiles, parking pavements, footpath pavements, tennis grounds etc.

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