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Experimental Investigation and Comparative Study On the Strength of Ordinary Concrete and LWC Using Vermiculite Mineral

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Abstract

In recent development scenario, the lightweight concrete is a versatile material which offers a range of technical, economic and environmental-enhancing and preserving advantage and is designed to become a dominant material in the millennium. For structural application of light weight concrete, the density is often more important than the strength. A decreased density for the same strength level reduces the self-weight, foundation size and construction cost. Structural lightweight aggregate concrete is generally used to reduce dead weight of the structure as well as to reduce the risk of seismic damage to a structure because the seismic forces that will influence the civil engineering structures are proportional to the mass of those structures.

In this study, structural light weight aggregate concrete was designed with the use of natural vermiculite aggregate that will provide an advantage of reducing dead weight of structure and to obtain a more economical structural light weight concrete by the use of vermiculite power as a partial replacement of sand. Five mixes were produced with the cement content of 356 kg/m³ and water cement ratio 0.45. More over the group had proportion of 0%, 5%, 10%, 15% and 20% as vermiculite replacement.

The main scope of our project is to learn and gather knowledge of strength, and density. It may help us to get clear idea about the light weight concrete, using vermiculite

1. Introduction

Vermiculite is a member of the phyllosilicate mineral group and is micaceous in nature. It is found in many parts of the world but only a limited number of sources are worked as commercial deposits. The vermiculite is mined and refined using a variety of techniques and supplied commercially in a range of particle size grades of vermiculite concentrate (unexpanded).

VERMICULITE is the name used in commerce for a group of micaceous minerals that expand or exfoliate many times (commercial varieties esfoliate 8 to 20 times or more) the original thickness when heated. They show the characteristic micaceous structure of basal cleavage and occur as soft, pliable inelastic laminar. Their basal cleavages are not so perfect as those of mica.

Vermiculite exists in a wide range of colours from black through various shades of brown to yellow. Its chemical composition varies widely consisting of a complex hydrated aluminium, magnesium silicate and hence the analysis of the mineral is of little use in determining the vermiculite for commercial utility, a technical trial of the material provides the only satisfactory test.

Vermiculite owes its commercial utility to its property of exfoliation when heated. It exfoliates into a yellow to bronze coloured mass giving an appearance of a cluster of worms vermiculus, an Italian word for worm from which it has derived its name as vermiculite. Some authorities quote the Latin word vermiculari from which the name vermiculite might have been derived.

1.1 Classification of vermiculite

Class **:** Silicates (SiO4)

Subclass **:** Phylosilicates (The Sheet Structures)

Groups **:** The Clays and the Monmorillonite / Steatite The different varieties of vermiculite are,

- Batavite, Copper
- Eastonite (of hamilton)
- Lucasite (of chatard)

1.2 Characteristics of vermiculite

Colour **:** Brown to golden brown, can also be white, colourless, or yellow

Luster **:** Pearly to greasy **Transparency** **:** Translucent crystals
Cleavage **:** Perfect in one direction **Fracture** **:** Uneven to lamellar
Hardness **:** About 1.5, which can sometimes leave marks on . paper

Specific Gravity: 2.3-2.5

Streak **:** white

Crystal System **:** monoclinic, 2/m

1.3 Physical characteristics

Crystal Habit **:** Pseudo hexagonal tabular crystals ("books"), also compact or lamellar masses or microscopic crystals

Sintering temp **:** 1260 Degrees C

Melting Point:1330 Degrees C

Specific Heat: 1.8 kJ/kg K.

pH value **:** 8.0-9.5

Thermal Conductivity: 0.062-0.0656W/Mk

1.4 Fineness

Horticulture Vermiculite :1-2mm, 2-4mm Expanded Vermiculite:0-1mm, 1-3mm, 2-4mm
Insulation Vermiculite : 0-1mm, 0-2mm, 0-3mm

1.5 Shape and size

In general, the vermiculite particles are typically platelets, ranging in diameter from 0.04 µ to 4mm. The particle shape and size mainly depend upon the mineralogical phases and collection system. The particle shape affects the water demand of a standard paste and as the number of platelets' particles increase, the water demand decreases.

It was also reported that as the size of vermiculite decreases the requirement of water for mortars containing vermiculite increases. Studies on cement pastes showed that the spherical particles of fly ash initiate the nucleation leading to the mechanical interlocking of the needles and plates, which is responsible for the strength.

It was also observed that the particle size distribution mainly influence vermiculite reactivity at early ages while chemical composition and amorphous phase play a predominant role at the later ages.

1.6 Density

The density of vermiculite depends on the constituents (iron, silicon, alumina and silica, magnesium etc). The density of raw vermiculite is 50 to 90 lbs. per cu. ft. While that of the exfoliated one is 5-10 lbs. per cu. ft. It. The colour of fly ash may vary from light tan or grey to almost black depending on the type and quality of the coal used and combustion process.

1.7 Chemical characteristics

Vermiculite is a fine particulate material with the main chemical constituents being SiO2, AlO3, Fe2O3 and CaO which are responsible for its pozzolanic activity. It also consists of MgO, Mn203, P2O5, SO3, Na2O andi. There is a possibility for variation in composition from plant to plant and even in one plant from time to time. SiO, 38-46,MgO 16-24,Al_2O, 11-16,Fe2O3 8-13,KO 4-6,CaO 1-3,TiO:1-3,MnO.1-0.2,Cr_2O, 0.05-0.2,Na:O 0.1-0.3.

Vermiculite crystallizes in the monoclinic system, and the crystal faces are often marked with triangular lines at 60 degrees and 120 degrees. X-ray studies have indicated that vermiculite constitutes a specific type with a definite structure differing from that of mica or chlorite. The main composition are in vermiculite are Silica, 31-41% Alumina, 10-17% Iron oxides, 5-22% Magnesium oxide, 11-13%.

1.8 Chemical reaction of vermiculite in portland pozzolona cement concrete

The principle product of the reactions of fly ash with calcium hydroxide and alkali in concrete is the same as that of the hydration of Portland Pozzolona cement, i.e. Calcium Silicate Hydrate (C-S-H). The morphology of the vermiculite reaction product is suggested to be more gel-like and denser than that from Portland Pozzolona cement. The reaction of vermiculite continues to consume calcium hydroxide to form additional C-S-H as long as calcium hydroxide is present in the pore fluid of the cement paste

1.9 Applications

Vermiculite is always used in exfoliated form. When exfoliated it possesses nearly 10 to 11 times less bulk density than the original volume. In commerce, vermiculite which expands more than 10 times the original volume is regarded of good quality. vermiculite is considered of low grade.

The low bulk density, comparative high refractoriness, low thermal conductivity and chemical inertness make vermiculite satisfactory for many types of thermal and acoustic insulations. One of its large commercial uses is as an aggregate in light weight concrete and hard wall-plaster because of its acoustic and thermal insulating and fire-resisting qualities. The density of raw vermiculite is 50 to 90 lbs. per cu. ft.

While that of the exfoliated one is 5-10 lbs. per cu. ft. It is therefore extensively used in concrete work to save weight. Vermiculite concrete weighs 20-25 per cu. ft. as against and concrete which weighs about 100 lbs. per cu. ft. Vermiculite concrete has the same advantages as concrete made with pumice and perlite.

Refractory insulations both in the form of loose vermiculite fill and vermiculite bricks are used in furnaces and kilns up to 1100°C. About 60% of the present world consumptions is in the form of loose fill when the expanded material is merely pured like dry sand into wall spaces or applied over ceiling constructions or attics of residential buildings with a view to insulating homes against cold in winter and heat in summer.One inch of Unifil, a trade name of a particular expanded vermiculite, holds back as much of 2% ft. brick wall or wall of concrete 3% ft. thick. As a light-weight aggregate it is extensively used in prefabricated houses. Vermiculite concrete in the form of monolithic cast is used in sound-absorbing panels in sheds. Vermiculite, being a granular expanded aggregate with numerous air voids, when mixed with a suitable binder develops sound insulating properties.

Vermiculite plaster is widely used for better acoustics and reduction of noise in auditoriums, wireless studios, theatres, hospitals etc.

Vermiculite mixed with three parts of gypsum is used as plaster for sound- absorbing purposes. A new building material called Pyrok, consisting of vermiculite bonded with lime and cement is marketed in England. More than hundred major and minor uses of vermiculite have been developed in the fields of agriculture, pesticides, lubricants, disinfectants, insulating bricks.

A Canadian steel company ships red hot steel ingots for a distance of 288 km from open hearth to mill plant, embedded in loose vermiculite. A temperature loss of less than 9 per cent is reported. The vermiculite is reused.

Un exfoliated vermiculate has a few minor uses, such as for circulation in drilling mud and in the annealing of steel. When un exfoliated vermiculate is reacted with concentrated H2SO4, it produces a pure form of silica in flake form. This product is known as 'samisilite'.

1.10 Lightweight concrete

Beneficial effects of supplementary cementing materials like vermiculite, on reducing the weight of the concrete.

- ❖ Formation of a denser microstructure of calcium silicate hydrate (CSH) due to the additional hydration products formed by pozzolanic reactions.
- ❖ Modification of the pore structure of the cement paste. The products of reaction of vermiculite particles taking place within the capillary pores of the cement hydrate may block some pores and make them discontinuous. The average pore size becomes smaller, although the total porosity may remain the same.
- ❖ Increased impermeability of concrete. This results from denser microstructure of the cement paste, increased volume of reaction products and improvement in the workability of concrete, which permits fuller compaction.
- ❖ Lower electrical conductivity of concrete. Addition of vermiculite has been found to increase the resistance to the flow of (electrochemical) corrosion currents in concrete
- ❖ Increased chloride binding Presence of aluminate phases in vermiculite encourages binding of chloride ions in the pore solutions. Chloride binding is also aided by adsorption on the surfaces of the vermiculite
- ❖ pH value of the pore solution is maintained. Alkalinity in pore solutions in the cement paste is not due to Ca(OH): alone. Alkalies, aluminate and silicate hydrates also contribute to the pH value. This has been established by elaborate tests, which showed the pH value in hydrating systems with pozzolana or slag to be at least 12 or more.

Lightweight aggregate concrete can be produced using a variety of lightweight aggregates

Lightweight aggregates originate from either.

- Natural materials, like volcanic pumice.
- The thermal treatment of natural raw materials like clay, slate or shale i.e. Leca.
- Manufacture from industrial by-products such as fly ash, i.e. Lytag
- Processing of industrial by-products like FBA or slag.

The required properties of the lightweight concrete will have a bearing on the best type of lightweight aggregate to use. If little structural requirement, but high thermal insulation properties, are needed then a light, weak aggregate can be used. This will result in relatively low strength concrete.

Lightweight aggregate concretes can, however, be used for structural applications, with strengths equivalent to normal weight concrete.

The benefits of using lightweight aggregate concrete include:

- Reduction in dead loads making savings in foundations and reinforcement.
- Improved thermal properties.
- Improved fire resistance.
- Savings in transporting and handling precast units on site.
- Reduction in formwork and propping

Foamed concrete

Foamed concrete is a highly workable, low-density material which can incorporate up to 50 per cent entrained air. It is generally self-levelling, self- compacting and may be pumped. Foamed concrete is ideal for filling redundant voids such as disused fuel tanks, sewer systems, pipelines, and culverts - particularly where access is difficult. It is a recognised medium for the reinstatement of temporary road trenches. Good thermal insulation properties make foamed concrete also suitable for sub-screeds and filling under-floor voids.

Autoclaved aerated concrete (AAC)

AAC was first commercially produced in 1923 in Sweden. Since then, AAC construction systems such as masonry units, reinforced floor/roof and wall panels and lintels have been used on all continents and every climatic condition. AAC can also be sawn by hand, sculpted and penetrated by nails, screws and fixings.

1.10.1 Advantages of light weight concrete Fireproof

The fireproofing characteristics of vermiculite concrete are recognized nationwide by insurance companies, state rating bureaus and local building officials. Underwriters Laboratories have assigned up to 4-Hour ratings to systems that employed vermiculite as one of the components.

Insulation

Vermiculite concrete has excellent insulating properties. Three inches of vermiculite concrete is equivalent to 1 1'2" of rigid board insulation layed over steel decks. One inch of vermiculite concrete is equal in insulating value to 20 inches of regular concrete.

Ease of Application

Vermiculite insulating concrete is easily placed by modern specially designed pumping equipment. Up to 25,000 square feet can readily be placed in one day.

1.10.2 Special features:

Reroofing

Slope to drain systems employing vermiculite concrete and polystyrene ventboard provide an economical solution to existing flat roofs.

Substrates

Vermiculite concrete is suitable for installation over most structurally sound roofing systems with structural decks of concrete, metal, or wood. Care must be taken to properly vent decks poured over impervious materials.

1.10.3 World Resources

There are three important mining centres of vermiculite in the world. These are

- Palabora in the Transvaal, Rep. of South Africa
- Montana (USA)
- South Carolina (USA)

The transversal is by far the best known in the world and it supplies all European countries. USA also imports considerable quantities from Transvaal for its better quality and blending qualities. There countries reporting negligible to small production are Kenya, Tanzania and Malawi in Africa, Queensland, South Australia, Western Australia, Argentina, Brazil, Egypt and Japan.

Transvaal

Vermiculite is mined at Phalaboreva in Palabora district. It is the largest mine of vermiculite in the world. The mineral occurs in the serpentinised pyroxenite of nature. complex The mine is worked by the open pit benching method, the benches being 5 metres high and from 9-45 metres wide. 150,000 tonnes of rocks are removed from the mine each month consisting of 60,000-70,000 tonnes of ore with 40 to 45% vermiculite. The Transvaal Ore Co. Ltd., markets 5 grades of vermiculite.

Raw vermiculite is prepared by crushing, drying, screening and winnowing. The ore is dried in rotary coal-fired driers at a temperature of 600°F. The dried material is of different sizes of which the +5/8 in. variety is reduced in hammer mills, screened into various sizes and cleaned by winnowers which concentrate, middlings and waste. Middlings, mainly small thick 'books' of vermiculite, are returned to the hammer mills to be reprocessed.

USA

Montana: The deposit is situated in Lincoln county near Libby.

Vermiculite is associated with pyroxenite and biotite. The rock mass grades nearly pure biotite and vermiculite. Vermiculite is found as a lenticular vein fi to 30 metres wide and 300 metres long

South Carolina
The vermiculite is mined in Piedmont in western South Carolina.

Vermiculite is found in an altered mass of pyroxenite in the country rock of schists and gneisses. The upper portion of altered pyroxenite is vermiculite and the lower portion of altered pyroxenite is vermiculite and the lower portion is biotite

Note: In all vermiculite has been reported in 14 states

of the United States. Besides Montana and South Carolina, the other important producing states are California, Colorado, Georgia, North Carolin.

Canada
The most important deposit is located at Stenley ville near Perth, Ontario and it has been observed over an area nearly three-fifth of a mile long and in many places one-sixth of a mile wide. Production of vermiculite in Canada is small.

1.10.4 Special contents in light weight concrete

- Light Weight
  Density range from 650 Kg/m³ to 1850 Kg/m² as compared to 1800 Kg/m³ to 2400 Kg/m³ for conventional brick and concrete respectively. Despite millions of tiny air filled cells, it is strong and durable. There is Lightweight advantage for the structure design, leading to savings in supporting structures and foundation. Compressive Strength: 2.0 to 7.0 N/mm²
- Excellent Acoustic Performance.
  It can be used as effective sound barrier and for acoustic solutions. Hence, highly suitable for partition walls, floor screens/roofing and panel material in auditoriums
- Earthquake Resistant
  Since lighter than concrete & brick, the lightness of the material increases resistance against earthquake.
- Insulation
  Superior thermal insulation properties compared to that of conventional brick and concrete, so reduces the heating and cooling expenses. In buildings, light-weight concrete will produce a higher fire rated structure.
- Workability:
  Products made from lightweight concrete are lightweight, making them easy to place using less skilled labour. The bricks can be sawed, drilled and shaped like wood using standard hand tools, regular screws and nails. It is simpler than brick or concrete.
- Lifespan
  Weather proof, termite resistant and fire proof.
- Savings in Material
  Reduces dead weight of filler walls in framed structures by more than 50% as compared to brickwork resulting in substantial savings. Due to the bigger and uniform shape of blocks, there is a saving in bed mortar and plaster thickness. In most cases the higher cost of the light-weight concrete is offset by

a reduction of structural elements, less reinforcing steel and reduced volume of concrete.

- Water Absorption
  Closed cellular structures and hence have lower water absorption,
- Skim Coating
  Do not require plaster and water repellent paint suffices. Wallpapers and plasters can also be applied directly to the surface
- Modulus of Elasticity
  The modulus of elasticity of the concrete with lightweight aggregates is lower. 0.5-0.75 to that of the normal concrete.Therefore more deflection is there in lightweight concrete.

1.10.5 Types of light weight concrete

- Using lightweight aggregates
  This type is produced using lightweight aggregate such as brick bat. volcanic rock or expanded clay. It can be produced with the use of naturally mined lightweight aggregates (bulk density in the range of 880 kg/m³) or manmade lightweight aggregates like "Aardelite" or "Lytag" (bulk density 800 kg/m²).

- Using foaming agents
  This one is produced through the addition of a foaming agent in cement mortar. This creates a fine cement matrix which has air voids throughout its structure. Aerated cement mortar is produced by the introduction of a gas into cementations slurry so that after hardening a cellular structure is formed.

1.10.5.1 Light weight aggregate

Lightweight aggregates used in structural lightweight concrete are typically expanded shale, clay or slate materials that have been fired in a rotary kiln to develop a porous structure. Other products such as air cooled blast furnace slag are also used. Also there are some non-structural lightweight aggregates with lower density made with other aggregate materials and higher air voids in the cement paste matrix. These are typically used for their insulation properties.

1.10.5.2 Natural Aggregates

- Inorganic Natural Aggregates
  Diatomite, pumice, scoria and volcanic cinders are natural, porous volcanic rocks with a bulk density of 500-800 kg/m³ which make a good insulating concrete
- Organic Natural Aggregates
  Wood chips and straw can be mixed with a binder to provide a lightweight natural aggregate. These are cellular materials which have air trapped within their structures once they have low moisture content.

1.10.5.3 Manufactured aggregates:

- Bloated clay sintered fly ash and foamed blast furnace slag
- Lightweight expanded clay aggregate: This is produced by heating clay to a temperature of 1000-

1200°C, which causes it to expand due to the internal generation of gases that are trapped inside. The porous structure which forms is retained on cooling so that the specific gravity is much lower than what was before heating it.

- Foaming agents
  There are some foaming agents which when added to the cement slurry forms air voids
- The bulk density of fine lightweight aggregates is around1100 kg/m³.
- The bulk density of coarse lightweight aggregates is around 940 kg/m³

1.10.6 Scope and objective of present investigation

Structural lightweight aggregate concrete is an important and versatile material, which offers a range of technical, economic and environmental-enhancing and preserving advantages and is designed to become a dominant material in the new millennium.

It has many and varied applications: multistory building frames and floors, curtain walls, shell roofs, folded plates, bridges, pre stressed and pre-cast elements of all types and others. Structural lightweight aggregate concrete generally used to reduce dead weight of structure as well as to reduce the risk of earthquake damages to a structure because the earthquake forces that will influence the civil engineering structures and buildings are proportional to the mass of those structures and buildings

Thus, reducing to the mass of structure or building is utmost important to reduce their risk due to earthquake acceleration. Also, reduction in the dead weight of a construction could result in a decrease in the cross-section of columns, beams, plates and foundations.

Higher strength/weight ratio, better tensile strain capacity, lower coefficient of thermal expansion and superior heat and sound isolation characteristics due to air voids of the lightweight aggregates are advantages of structural lightweight aggregate concrete.

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The objectives of the present investigation are

1. To study the strength vermiculite blended concrete under various replacement levels (5%, 10%, 15%, 20%, in comparison to Portland Pozzolona Portland cement concrete.

2. To find out the tolerable limit of replacement of vermiculite in cement for durable steel reinforced concrete.

2 LITERATURE REIVEW

2.1 Litreture review on vermiculite concrete

ASIK, Mesut et.al..(2012) have reported that when 25% of cement was replaced by vermiculite, based on first 300 kg/m² of cementations material, the 28-day compressive strength compared to the control mix, and second 500kg'm also the water cement ratio of groups were 0.49 and 0.35 respectively The optimal vermiculite replacement was found to be 35% at 300 kg/m³ of cementations material.

According to results of experimental study, it was concluded that natural vermiculite aggregate can be used in the production of structural lightweight aggregate concrete. Based on the strength and density results of experimental work, it is possible to produce lightweight concrete with 20MPa 40MPa cylindrical compressive strength by using natural vermiculite aggregate. Also, the use of vermiculite powder, which will provide economy, can reduce dead weight further and increase performance

A.Al-rodan and S. Al-tarawnah et.al., (2012) conducted finite element analysis of the flexural behavior of vermiculite with high-strength concrete. This aim was to verify the newly published design regulations of Eurocode-4 for high strength concrete. The comparison between the numerical results obtained and the experimental ones demonstrates the validity of the finite element model. The experimental results are also compared to the Eurocode-4 predictions. The finite element load displacement curves for different aspects show satisfactory agreements. The test results of the experimental investigation reported and the finite element analysis results show that EC4 yields conservative predictions for the failure loads of hollow structural concrete filled tube beams.

Mr. Arivalagan And Mr. Kandasamy etal, (2013) was conductal study on energy absorption capacity of composite beats. Thus aims to study the experimental behavior of vermiculite mineral for which Two types of fillet maternal were used (normal mix concrete and fly ash concrete) Totally nine specimen consisting of three rectangular hollow specimens and six concrete filled steel tibes Concrete filled strel tubes consisting of three normal mix concrete specimens and three vermiculite light weight concrete specimens were used

How-Ji Chen Chung-Ho Huang: and Chao-Wei Tang et.al(2014) The primary design varables included compressive strengths of 20, 40, and 60 MPa and reinforcement ratios of 0%, 1.03%, and 2.12%, respectively. A total of 62 beans were made and tested. Test results showed that the unit weight of LWAC beams was about 16-23% lower than that of NWC beams for the same strength level. In addition, the reduced modulus of elasticity of LWAC resulted in a stiffness decrease of reinforced lightweight concrete (RLC) beams of 5-15% related to the reinforced NWC (RC) beams. Nevertheless, the natural frequency of RLC was still higher by about 1-10% than that of RC. In contrast, it was also found that the porous LWA with high damping capacity enhanced the damping ratio of RLC beams by 13-30% for concrete strength in the range from 20 to 60 MPa. As a whole, the lower the concrete strength is (eg.. 20 MPa), the more effective will be for the lightness of LW AC beam and the damping ratio, which in turn is more favorable to the seismic resistant efficiency of LWAC beam.

Schackow et al., (2014) Mechanical & thermal properties of lightweight concretes— experimental This study aimed to compare mechanical and thermal properties of lightweight aggregate concrete with two kinds of lightweight aggregates, vermiculite and Expanded Polystyrene (EPS) and using air-entraining agent and superplasticizer admixture. For better reliability, a statistical analysis of the results compressive strength and density was used. The factors of the 2^2 full factorial design were: amount of lightweight aggregate (55% and 65%) and quantity of air-entraining agent (0.5% and 1.0%). The results showed that the addition of air-entraining agent left the lightweight concretes even lighter, but less resistant. EPS lightweight concrete has higher strength and is lighter than with vermiculite. Vermiculite lightweight concrete had lower thermal conductivity than with EPS. The better lightweight aggregate content was 55%.

Przychodzień & Katzer, (2021) Properties of structural LWAC modified with exfoliated vermiculite (Materials)Despite the undoubted advantages of using lightweight concrete, its actual use for structural elements is still relatively small in comparison to ordinary concrete. One of the reasons is the wide range of densities and properties of lightweight aggregates available on the market. As a part of the research, properties of concrete based on sintered fly ash were determined. The ash, due to its relatively high density is suitable to be used as a filler for structural concretes. Concrete was based on a mixture of sintered fly ash and exfoliated vermiculite aggregate also tested. The purpose of the research was to determine the possibility of using sintered fly ash as alternative aggregate in structural concrete and the impact of sintered fly ash lightweight aggregate on its physical, mechanical and durability properties. Conducted tests were executed according to European and Polish standards. Created concretes were characterized by compressive strength and tensile strength ranging from 20.3 MPa to 54.2 MPa and from 2.4 MPa to 3.8 MPa, respectively. The lightest of created concretes reached the apparent density of 1378 kg/m^3.

Assis Neto et al., (2023) Expanded Vermiculite: review about production & effects on mortars**.** Global temperatures have led to an increasing need for air conditioning systems. So, because of this fact, buildings have been improved in terms of their thermal and energy efficiency. Regarding this, the Brazilian standard ABNT NBR 15.575-4/2013 set minimum parameters for the thermal transmittance and thermal capacity of sealing elements, which allow classifying the thermal efficiency of the building. In order to comply with the requirements, the usage and study of lightweight construction materials have been in focus. An example of these materials is vermiculite. The present research reviewed articles about expanded vermiculite. The study involved the examination and comparison of various articles to analyze the properties of vermiculite and the impact of its usage on coating mortars. It was possible to verify that using vermiculite in mortars caused bad workability and a decrease in mechanical strength. However, the porosity and water absorption in mortars increased. Additionally, it reduced the specific weight and the thermal conductivity of the mortars, allowing for a better thermal insulation of the rooms. As an alternative to decreasing the negative effects of vermiculite, it is possible to use chemical admixtures, mineral additions, and mix design with a greater consumption of binder or a combination of particle sizes.

Ganasen et al.(2023) Experimental investigation—vermiculite concrete bricks (Frontiers/Materials)
This study embarks on an in-depth exploration of mortar enhanced with Expanded Vermiculite Aggregate (EVA) defined as Expanded Vermiculite Mortar (EVM), aiming to fill notable gaps in the current body of research regarding its acoustic properties and behavior under both quasi-static tensile forces and dynamic compressive loads. Leveraging an extensive series of experimental tests, this research meticulously examines a broad spectrum of physical and mechanical characteristics, including density, water absorption ratio, thermal conductivity, sound absorption coefficient, sound transmission loss, as well as quasi-static compressive and splitting tensile strengths, and dynamic compressive behavior under high-strain rates. Additionally, this study includes a micro-structural analysis to elucidate the impact of expanded vermiculite on the Interfacial Transition Zones (ITZ) between the cement paste and aggregates, providing critical insights into the material's enhanced performance and failure mechanisms at the microscopic level. This study highlights that the inclusion of EVA in mortar significantly enhances its sound absorption capabilities attributable to the aggregate's porous structure and the increased overall porosity. Conversely, thermal conductivity tests reveal a marked decrease in heat transfer through the mortar with EVA substitution, underscoring its potential to improve thermal insulation in building applications. The study reveals that while EVA incorporation leads to a decrease in both compressive and tensile strengths of mortar, it introduces beneficial alterations in material behavior, including increased energy absorption and altered failure modes under dynamic loading conditions. The study introduces a probabilistic, data-driven model to predict the Dynamic Increase Factor () based on strain rate and EVA substitution level, offering novel insights into the material's behavior under such conditions. This comprehensive investigation not only advances our understanding of EVM's potential in construction applications but also provides a foundational dataset for future research endeavors aimed at optimizing the material's composition for enhanced structural and thermo-sound insulation properties.

Balbuena et al.(2024 / 2025). Lightweight mortar w/ aerogel, perlite, vermiculite Climate change is compelling countries to alter their construction and urbanization policies to minimize their impact on the environment. The European Union has set a goal to reduce greenhouse gas emissions by 55%, recognizing that 50% of its emissions originate from maintaining thermal comfort within buildings. As a response, the EU has developed comprehensive legislation on energy efficiency. In this article, special mortars using aerogel, perlite, and vermiculite as lightweight aggregates were prepared and studied to enhance the thermal properties of the mortar. Their thermal properties were examined and, using a solar simulator for both hot and cold conditions, it was found that varying proportions of these lightweight aggregates resulted in a mortar that provided insulation from the exterior up to 7 °C more than the reference mortar in warm conditions and up to 4.5 °C in cold conditions.

Puppala et al. / Preethi & Ashveen (2022). Concrete with replacement of fine aggregates by vermiculite and cement by silica fume (conference / Indian journals) This paper aimed to compare the mechanical aspects of light weight concrete of M30 concrete with and without silica fume as replacement to cement by 10% along with sand as partial replacement of 0%,5%,10%,15%,20% and 25%variations of vermiculite. Specimens are tested for compressive strength using 10cm X 10cmX10cm cubes for 7, 14, and 28 days flexural strength was determined by using 10cmX10cmX50cm prisms at 28 days and split tensile strength is determined using 15cm diameter and 30cm height cylinder specimens at 28 days The test show that it is possible to produce a natural light weight concrete with increase in mechanical properties using vermiculite and silica fume.

S.JyothiManjula,G.VijayMano,J.SundarPrabu,M.Prabanjan,S.Pradeep (2018) This paper presents the experimental investigation of light weight self compacting concrete.(LWSCC) for M30 grade of concrete using pumice stone, expanded perlite, exfoliated vermiculite test were conducted on hardened concrete for compressive,split tensile,flexural, and impact and also on fresh concrete for Slump test, flow test, vee-bee consistometer,compaction factor tests were done. Further selfcompacting concrete for M30 the proportion of coarse aggregate is replaced by pumice stone, vermiculate and perlite at vartions of 2.5%, 5%, 7.5%, 10%,12.5% and 15%it was found that the light weight aggregate replacement for coarse aggregate with percentage like 2.5% to 15%.from 2.5% to 7.5 % replacement given good results. But beyond 7.5%.Has reduced the mechanical properties when compared with conventional concrete.

M.V.S.S.Sastry, P.Ashveen Kumar,.K.JagannadhaRao(2018) In this experimental study, the mechanical properties of M20 grade concrete with different percentages at a range of 0-100% at an increment of 20% as partially replacement with vermiculite to the total weight of fine aggregate along with mineral admixtures like Ultra fine Fly ash (UFA) and micro silica (SF) is replaced with cement by various percentages i.e., from 5-15%, and Micro silica (SF) at 5%, 10% and 15% by weight of cement. The compressive strength at all ages is decreasing due to the replacement of Exfoliated Vermiculite (EV), but an economical design was obtained with 20% replacement to sand.

T.Subramani, M.Meghnathan. S.Priyanka(2017) This paper presents investigation on Fiber Reinforced High Strength Concrete. Using recycled aggregate for 20% and40% replacement of coarse aggregate for M30 grade of concrete with replacement of natural sand with vermiculite mineral with varying percentages. And 1% steel fibers is also used and compared with conventional concrete casted using plastic fibers. all the specimens are tested for 28 days using cubes and cylinders and tested for compressive strength,split tensile strength and workability. Investigation resulted that strength of vermiculite concrete although decreased but was increased using super plasticizer and usage of vermiculite had given less density proving to be suitable for light weight structures. **A.V.V.Sairam,K. Sailaja (2017)** This paper presents Mechanical Properties onM35 grade concrete mix for varying percentages with 5%,10%15%20% 25% and 30% replacement with vermiculite to fine aggregate along with fly ash to replace cement with varying percentages of10%15% and20%and silica fume as additive to cement with varying percentages of 5%7.5%10% and12.5%with constant water cement ratio of 0.42 and it was found that10% of silicafume and 15% flyash and 5%vermiculite has given optimum increase in compressive strength whereas10%silicafume and 10%flyash with 5%vermiculite has given increase in split tensile strength compare to concrete with no vermiculite.

Ramapradheep. G.S, M.Sivaraja(2017) This paper presents Experimental investigation on self compacting self curing concrete using light weight aggregate for M40 grade using 5%,10% LECA as and 5%,10% replacement to fine aggregate and test was conducted using cubes and cylinders the workability and mechanical properties improved for 10% LECA and 10% vermiculate as a partial replacement of fine aggregate . Thangam.D,Geetha.V(2017) This paper presents Experimental investigation on self curing concrete for M20 grade using vermiculite and GGBFS 50% of ggbfs as replacement to cement and vermiculite with diff variations of 20%,40%,60% and80% with fine aggregate and it was found that 20% replacement with fine aggregate and 50% ggbfs replacement to cement used for casting of self curing. concrete has given good strength. With usage of poly ethylene glycol as self curing agent.

S.Syed Abdul Rahman,Gijo.K.Babu(2016) the paper presents about M30 grade of concrete to know variation in density of concrete with and without vermiculite. For constant water cement ratio of 0.40 for different variation 0%,5% and10% of replacement of natural sand with vermiculite powder and it was found that there is decrease in strength with increase in vermiculite but decrease in density from 2486 to 2167 kgs/m3 with proves that use of vermiculite decrease the self weight of concrete with slight decrease in compressive strength.

M.R.Divya.,Prof.M.Rajalingam,Dr.SunilaaGeorge(2016) This paper presents study of M30 grade concrete mechanical properties experimental set up were done by replacing fine aggregate with vermiculite passing through 2.36mm sieve by 40%,50%and60%by weight it was found that concrete mix with replacement with 40% vermiculite has given increase in compressive strength, split tensile strength and flexural strength alternately indicates use of high percentage of vermiculite that is beyond 40% as replacement to fine aggregate reduce the strength.

2.2 Experimental investication and development of locally produced light weight aggregate concrete.

Mostafa a.m. Abdeen, hossam hodhod et.al., Vermiculite produced by Egyptian Vermiculite Company was used to replace sand. It is usually applied as heat insulator and have a light weight (SG-0.55). Particles of vermiculite are almost round and have size in the range of 1-5mm.

Through the course of this study, ten concrete mixes of normal and light weight concrete were evaluated. LWC was produced using local processed and recycled aggregate in Egypt. Results showed the potential of local aggregate to achieve weight reduction of about 40%. However a corresponding reduction in strength was inevitable. Similar reduction in stiffness was observed too. However, it could be compensated for by applying fiber reinforcement. The application of LWC appeared to be promising in increasing impact and elevated temperature.

2.3 A study report in international standard organization (iso) (1999)

International Standard Organization et.al It provides the first draft for International Standard that applies to Vermiculite structures based on their performance and on limit state design. The limit states are defined as states beyond which the structure no longer satisfies the design performance stipulations. The two limit states are split into ultimate limit states and serviceability limit states.

Ultimate limit states are those related with structural failure which may jeopardize the safety of people. Serviceability limit states match up to states beyond specified criteria. This International Standard is only worried about the necessities for serviceability, mechanical resistance, and durability of structures.

Vermiculite used as composite makeup may require additional considerations beyond this Standard. This article is a compliment of Determination of Physical and Mechanical Properties of Vermiculite (1999) and Laboratory Manual on Testing Methods for Determination of Physical and Mechanical

Properties of Vermiculite (1999).

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The exfoliated vermiculite is used as an filler material and developed an cement tiles exhibiting low water absorption, better strength properties compared with the traditional famous conventional tiles used for flooring tile purpose. It is light in weight and easy to handle. The special characteristics and usage of this material would decrease the structural weight and it is quite good material if it is replaced partial form gives better results. In order to obtain desired consistency, polymer admixture such as SBR latex and super plasticizer (1% weight of cement) was added in the mixes at 0.15 polymer cement ratio. The compression strength of the mortar cube for 28 days of curing for about 4.8 to 5.0 mpa and the flexural strength of about 2.9 to 3.5 mpa

Comparatively the weight of concrete is much lesser than the conventional concrete and weight of vermiculite insulated concrete is less than 6kgs for 20% replacement in fine aggregate when compared with the weight of conventional concrete lies between 8.5 to 9.5 kgs. The mechanical and thermal properties is compared by using light weight aggregates (55% to 65%), vermiculite, expanded polystyrene (0.5% to 1.0%) and super plasticizer admixture. EPS light weight concrete has higher strength and is lighter than with vermiculite. But vermiculite light weught concrete has lower thermal conductivity than with EPS. The better light weight aggregate content was 55%. Organo-vermiculites were used as antibacterial nanofillers to polyethylene. The components of vermiculite insulating concrete are expanded vermiculite aggregate, air entraining admixture, Portland cement, and water. all mixed and applied according to precise procedures. The ratio of cement to aggregate determines the density, strength and insulating values of the finished concrete. As used in the average roof deck, the ratio ranges from 1:4 to 1:8 by volume. Vermiculite concrete is installed in thickness of 2 inches and greater, depending on design needs and requirements.

M.R.Divya et al., (2016)
Have study on M30 grade concrete using vermiculite as partial replacement with 40%, 50% and 60% to the total weight of fine aggregate. The aim of their project is to study the strength parameters such as compressive strength, split tensile & flexural strength of concrete. They study result shows the optimum strength in compare the strengths for different vermiculite percentage was observed to be 50%.

S Syed Abdul Rahman and Gijo K Babu (2016)
In their study, structural light weight aggregate concrete was designed with the use of natural vermiculite aggregate that will provide an advantage of reducing dead weight of structure and to obtain a more reasonable structural light weight concrete by the use of vermiculite power as a partial replacement of fine aggregate. Three mixes were created

2.4 structure and commercial use of vermiculite

2.4.1 Structure and commercial use
Vermiculite is a 2:1 clay, meaning it has 2 tetrahedral sheets for every one octahedral sheet. It is limited expansion clay with a medium shrink-swell capacity. Vermiculite has a high caution exchange capacity at 100-150 meq/100g. Vermiculite clays are weathered micas in which the potassium ions between the molecular sheets are replaced by magnesium and iron ions.

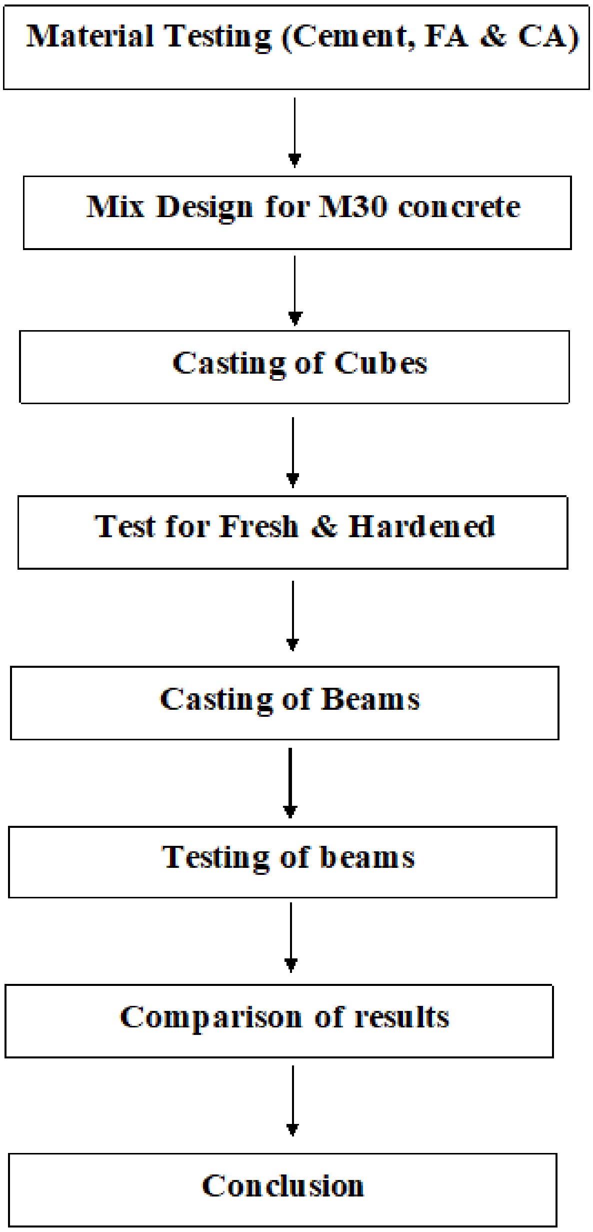
2.4.2 Commercial uses

- As an additive to fireproof wallboard
- As a component of the interior fill for fire stop pillows, along with graphite
- As a carrier for dry handling and slow release of agricultural chemicals
- As a growing medium for hydroponics.
- As a hot topping: both exfoliated and crude vermiculite have been used for hot topping in the steel industry. When poured onto molten metal crude vermiculite exfoliates immediately and forms an insulating layer allowing the material to be transported to the next production process without losing too much heat.
- Used to permit slow cooling of hot pieces in glassblowing, lamp work, steelwork, and glass bead making.
- Used in commercial hand warmers
- Used as a sterile medium for the incubation of reptile eggs
- Light-weight insulative concrete
- Used in AGA cookers as insulation
- Used in explosives storage as a blast mitigant
- Used to absorb hazardous liquids for solid disposal
- Used in gas fireplaces to simulate embers
- Used as part of a substrate for cultivation.

3. METHODOLOGY

The methodology worked out to achieve the above-mentioned objectives is followed as shown in the flow chart below:

Fig 3.1 Methodology



3.1 Material testing

3.2 General

To investigate the properties of the materials such as cement, fine aggregate and coarse aggregate used for casting the specimens. Various laboratory tests were performed and the test results obtained were compared with the Indian Standard values. The test results are tabulated below.

3.2.1 Test for cement

The following experiments were conducted to find the properties of cement as per IS-4031

I. Standard Consistency Test
II. Initial Setting Time and Final Setting Time Test III.Fineness Test
IV. Specific Gravity Test
V. Compression Strength test for Mortar Cube

These results have been tabulated in table 3 1 to table 3.5

Table 3.1.1 Standard Consistency of Cement:

Weight of cement (gm)	Percentage of water added(in terms of weight of cement)	Volume of water added(ml)	Penetration from bottom (mm)
400	28	112	37
400	30	120	36
400	32	128	31
400	34	136	25
400	36	144	16
400	38	152	6

Table 3.1.2 Initial Setting Time of Cement:

Time at which water is added to cement(min)	Time at which the needle fails to pierce the test block by 5.0± 0.5mm(min)	Initial setting time (min)
0	**45**	**45**

Table 3.1.3 Final Setting Time of Cement:

Time at which water is added to cement(min)	Time at which the needle makes an impression on surface of block(min)	Final setting time (min)
0	**445**	**445**

Table3.1.4 Specific Gravity of Cement:

S.NO	Description(kg)	Trial 1	Trial 2	Trial 3	Mean
1	Weight of pycnometer(W1)	675	675	675	3.15
2	Weight of pycnometer +cement +kerosene(W3)	1303	1309	1311	
3	Weight of pycnometer +cement (W2)	1775	1780	1783	
4	Weight of pycnometer +kerosene(W4)	1401	1401	1401	
5	Specific gravity	3.13	3.15	3.17	

CALCULATION:

$$\text{Specific gravity of cement} = \frac{W2-W1}{W2-WI\ (W2-W1)-(W3-W41x0.79}$$

$$= \frac{1.303-0.675}{(1.303-0.675)-(1.775-1.401)X0.79}$$

$$= 3.13$$

Table 3.1.5 Compressive Strength of Mortar Cube:

Sl.no	Period of curing(days)	Compressive strength(N/mm²)
1	3	34
2	7	44
3	15	54

Test report figures on cement test

3.2.2 Test for fine aggregate

The following experiments were conducted to find out the properties of fine aggregate as per IS 2386

i. Sieve Analysis Test
ii. Specific Gravity Test
iii. Water Absorption Test

The results have been tabulated in table 3.2.3.1 to table 3.2.3.3

Table 3.2.1 Sieve Analysis of Fine Aggregate:

SLNo	Sieve Opening Size	Weight of F.A Retained (gm)	Cumulative Weight of F.A retained (gm)	Cumulative Percentage of F.A Retained (gm)	Cumulative percentage of F.A passing
1	4.75mm	10	10	1.0	99.0
2	2.36mm	39	49	4.9	95.1
3	1.18mm	235	284	28.4	71.6
4	600µ	304	588	58.8	41.2
5	300 µ	290	878	87.8	12.2
6	150 µ	95	973	97.3	2.7
7	90 µ	25	998	-	0.2
8	Pan	0	0	-	-
				Total=278.2	

Calculation:

$$\text{Fineness modules} = \frac{\text{Total cumulative \% Weight retained}}{100}$$

$$= \frac{278.2\ 100}{100}$$

$$= 2.78$$

Table 3.2.2 Water Absorption of Fine Aggregate

Sl.no	Description	Trial
1	Weight of saturated surface dry sample (g)	1000
2	Weight of oven dry sample (g)	990.83
3	Water absorption	0.917%

Calculation:

$$\text{Water absorption} = \frac{W2-W1}{W1} \times 100$$

$$= \frac{(1000-990.83)}{1000} \times 100$$

$$= 0.917\%$$

Table 3.2.3 Specific Gravity of Fine Aggregate

S.NO	Description(gm)	Trial 1	Trial 2	Trial 3	Mean
1	Weight of pycnometer(W1)	681	681	681	2.77
2	Weight of pycnometer + sand(W2)	1415	1410	1419	
3	Weight of pycnometer +sand+full of water(W3)	2002	1999	2008	
4	Weight of pycnometer +water(W4)	1534	1534	1354	
5	Specific gravity	2.76	2.76	2.79	

Calculation

$$\text{Specific gravity of cement} = \frac{W2-W1}{(W4-W1)-(W3-W2)}$$

$$= \frac{(1415-681)}{((1534-681)-(2002-1415))}$$

$$= 2.76$$

3.2.3 Test for coarse aggregate

The following experiments were conducted to find out the properties of coarse aggregate as per IS-2386

i. Specific Gravity Test

ii. Impact Test

iii. Water absorption Test

iv. Sieve Analysis Test

The results are given in table 3.2.4.1 to table 3.2.4.4

Table 3.2.4 Water Absorption of Coarse Aggregate

SLno	Description(gm)	For size 20mm Aggregate
1	` Weight oven dry sample(W1)	1000
2	Weight of saturated Sample(W2)	1004
3	Water absorption	0.4%

Calculation:

$$\text{Water absorption} = \frac{W2-W1}{W1} \times 100$$

$$= \frac{1004-1000}{1000} \times 100$$

$$= 0.4\%$$

Table 3.2.5 Impact of Coarse Aggregate

SI.No	Weight of sample (A) kg	Aggregate Passed Through 2.36mm Sieve (B) kg	Weight Retained in Sieve (C) kg	Aggregate Impact Value(%)	Mean
1	575	41	534	7.1	7.1
2	580	42	538	7.2	
3	573	40	533	7.0	

Calculation

$$\text{Aggregate impact valve} = \frac{B}{A} \times 100$$

$$= \frac{41}{575} \times 100$$

$$= 7.1\%$$

Table 3.2.5 Specific Gravity of Coarse Aggregate

Sl.no	Description(gm)	Trial 1	Trial 2	Trial 3	Mean
1	Weight of empty bottle (W1)	681	681	681	2.54
2	Weight of bottle + Coarse Aggregate(W2)	1410	1412	1414	
3	Weight of bottle + Coarse Aggregate + water (W3)	1978	1978	1979	
4	Weight of bottle + water (W4)	1534	1534	1534	
5	Specific Gravity of Coarse Aggregate	2.55	2.54	2.53	

Calculation:

$$\text{Specific Gravity of Coarse Aggregate} = \frac{W2-W1}{(W4-W1)-(W3-W2)}$$

$$= \frac{1410-681}{(1534-681)-(1978-1410)}$$

$$= 2.55$$

Table 3.2.6 Sieve Analysis of Coarse Aggregate:

SI No	Sieve Opening Size (mm)	Weight of C.A Retained (gm)	% Retained	Cumulative Percentage of C.A Retained (gm)	Cumulative percentage of C.A passing
1	40	-	-	-	100
2	37.4	-	-	-	100
3	22.4	-	-	-	100
4	20	1030	51.5	51.50	48.5
5	10	966	48.3	99.80	0.2
6	4.75	3	0.15	99.95	0.05
7	2.36	-	-	100	-
8	1.18	-	-	100	-
9	600µ	-	-	100	-
10	300 µ	-	-	100	-
11	150µ	-	-	100	-
12	Pan	-	-	100	-
Total Cumulative Percentage of C.A Retained = 751.25					

Calculation:

$$\text{Specific Gravity of Coarse Aggregate} = \frac{\text{Total cumulative\% Weight Retained}}{100}$$

$$= \frac{751.25}{100}$$

$$= 7.5$$

3.2.4 Water

Ordinary tap water is used for concrete mixing in all the mix.

3.3 Mix design general

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required strength, durability and workability as economically as possible is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in two states, namely, the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The purpose of designing as can be seen from the above definitions in two fold. The first object is to achieve the stipulated minimum strength and durability. The second object is to make the concrete in the most economical manner. The cost of concrete is made up of the cost of materials, plant and labour. The variation in the cost of materials arise from the fact that cement is several times costly than the aggregate, thus the aim is to produce as lean mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking. For the investigation work M30 grade of concrete, the IS 10262: 2009 code of Mix Design was used.

3.3.1 Design data

Characteristic compressive strength required in the field at 28 day - 30 Mpa Maximum size of the aggregate - 20mm

Degree of workability - 0.8

Specific gravity of fine aggregate - 2.66

Specific gravity of coarse aggregate - 2.66

Specific gravity of cement - 3.148

Degree of quality control - Good.

Type of exposure - Mild

3.3.2 Determination of target mean strength

The target-mean compressive strength at 28 days = f ak +tS

= 30 + (1.65 * 5)

= 38.25Mpa

3.3.3 Determination of water cement ratio

Strength of concrete primarily depends upon the strength of cement paste. The strength of paste increases with cement content decreases with water content. Various parameters like types of cement, aggregate, maximum size of aggregate, surface texture of aggregate etc and influencing the strength of concrete, when water cement ratio constant. Hence it is desirable to establish a relation between concrete strength and free water cement ratio with materials and condition to be used. Here the water cement ratio adopted is 0.40

3.3.4 Determination of water and sand content

Required sand content as percentage of total aggregate by absolute volume = 35 + 0.5

= 35.5%

Required water content = 186Kg / (m ^ 3)

3.3.5 Determination of cement content

The cement content per unit volume of concrete may be calculated from free water cement ratio. And the quantity of water per unit volume of concrete (cement by mass water cement/water cement ratio)

W/C ratio = 0.40 Water = 186L

Cement = 465Kg / (m^3)

3.3.6 Determination of fine aggregate content

Aggregate content can be determined from the following equation.

$$V = W + \frac{c}{SC} + [\frac{1}{e} \times \frac{fa}{Sfa}] \times \frac{1}{1000}$$

$$0.98 = [191.6 + \frac{465}{2.77} + [\frac{1}{0.692} \times \frac{Ca}{2.54}] \times \frac{1}{1000}$$

$$Ca = 1102.126 \text{ Kg/m}^3.$$

3.3.8 Mix Proportion Table:

Water	Cement	Fine Aggregate	Coarse Aggregate
186(L)	465Kg	534.313Kg	1102.126Kg
0.40	1	1.15	2.37

3.4 Experimental investigation details

3.4.1 Materials used

Portland Pozzolona cement : Conforming to IS 456-2000

Graded fine aggregates : Local clean river sand (fineness modulus of medium sand equal to 2.46) conforming to grading zone III of IS-383 1970 was used.

Graded coarse aggregates : Locally available well graded aggregates of normal size greater than 4.75 mm and less than 12 mm.

Vermiculite used

The vermiculite collected from Andhra mines, India was used in as modified form by physical, chemical and thermal activation. The composition of Portland Pozzolona cement (PPC) and Vermiculite (VER) used are reported in Table 8.1.1.

TABLE.3.3.1 Constituents of vermiculite

Constituents	Vericahte (%)
SiO_2	46
Fe_2O_3	13
Al_2O_3	16
CaO	3
MgO	16
Loss on Ignition	0

3.5 TEST METHODS

Test on fresh concrete:

i. Slump Cone Test

ii. Flow Table Test

iii. Compaction Factor Test

iv. Vee Bee Test

3.5.1 Workability test on fresh concrete

Workability can be defined as the property of concrete which determines the amount of useful internal work necessary to produce full compaction. A mix must be workable enough to fill the form spaces completely, with the assistance of a reasonable amount of spreading and vibrating. Since a fluid mix does this more readily than a dry or stiff mix, one can see that workability varies directly with fluidity. The variation in workability characteristics of fresh concrete were determined by the slump test (IS: 5516-1996)

3.5.1.1 Slump Cone Test

Slump test is used to determine the workability of fresh concrete as per IS: 1199-1959. Slump test is the most commonly used method of measuring consistency of concrete. It does not measure all factors contributing to workability, not it is always representative of the place ability of the concrete. The apparatus used for conducting the test is slump cone (fig. 4.3), it consists of a metallic mould in the form of a frustum of a cone having the internal dimensions as under

Bottom diameter : 20 cm Top diameter : 10 cm Height : 30 cm

Table 3.3.2 Slump for each proposition

Sample	0%	10%	20%	30%	40%	50%
28days cube (mm)	77	90	85	98	120	110

Table 3.3.3 Workability of Concrete:

S.No	**Slump (mm)**	**Kind of work**
1	25 to 50	Road work Road Concrete
2	50 to 100	R.C beam and slab
3	75 to 125	R.C column

Fig 3.1 Slump Cone Test

3.5.2 Test on hardened concrete:

i. Compressive Strength - Cube and Cylinder Test

ii. Flexure Test

Test methods

a) Strength properties of the vermiculite blended concretes are studied by conducting the following tests: Cube compression test (as per BS-1881: Part 116: 1983) for 7, 14, 28 days of water curing to find out the compressive strength of concrete.

3.5.2.1 Compressive strength test: (7, 14, 28 days curing result)

150mm x 150mm x 150 mm concrete cubes were cast using 1:1.5-3 mix with W/C ratio of 0.53. Specimens with Pozzalona Portland cement and PPC replaced by vermiculite at 5%, 10%, 15%, 20% replacement levels were cast.
During moulding, the cubes were mechanically vibrated

The average compressive strength for Portland Pozzolona cement and vermiculite blended concrete (5% - 10% replacement levels) for different curing periods, vermiculite blended concrete shows adequate in compressive strength up to 20%. After 14 days curing, the vermiculite system up to 20% performs well comparing to control concrete.

3.5.3 Mixing and Filling of Concrete in Moulds

After cleaning the aggregates, batching process was started for 7, 14 and 28days cube, 28days cylinder. The different percentage of mixtures used as 0%, 5%, 10%, 15% and 20% partial replacement of vermiculite. For each proportion three specimens (cube + cylinder) has been tested for compressive strength and tensile splitting strength. The proportions used for cube and cylinder are given in the table below. The table shows batching process of 5 different % used in the process.

The batching process is done, water was added accordingly as per requirement and mixing was carried out by shovel by turning it over and over until uniformity in colour was achieved. Care was taken so as to avoid excess pouring of water. The homogeneous mixture so formed was filled in the moulds in 3 layers by tamping each layer 25 times so that voids get filled within the moulds and concrete is compacted.

Table 3.3.4 Size of the mould and specimen prepared

Sample	Size of the mould(mm)	Specimen prepared
7 days cube	150×150×150	18
14 days cube	150×150×150	18
28 days cube	150×150×150	18
28 days cylinder	150×300	6

3.5.4 Compaction

After preparing mould with concrete the same is taken to the tamping rod for proper compaction of the concrete and filling voids if any in the cube and cylinder. The mould is then covered with plastic sheet to prevent excess water from escaping. The hardened concrete samples are then demoulded after 24 hrs and submerged in a clean water bath for curing until the age of testing for days.

3.5.5 Curing of Concrete

Curing is done to prevent the loss of water which is essential for the process of hydration and hence for hardening. It also prevents the exposure of concrete to a hot atmosphere and to drying winds which may lead to quick drying out of moisture in the concrete and there by subject it to contraction stresses at a stage when the concrete would not be strong enough to resists them.

Fig 3.5.2 Filling of Concrete Mix in Cubes

Fig 3.5.3 Curing of Concrete

TABLE 3.3.5 Compressive strength of vermiculite replaced concrete after 7 days of curing

% of replacement	Average Compressive strength (N/mm²) (vermiculite)
0%	21
5%	21
10%	21
15%	18
20%	17

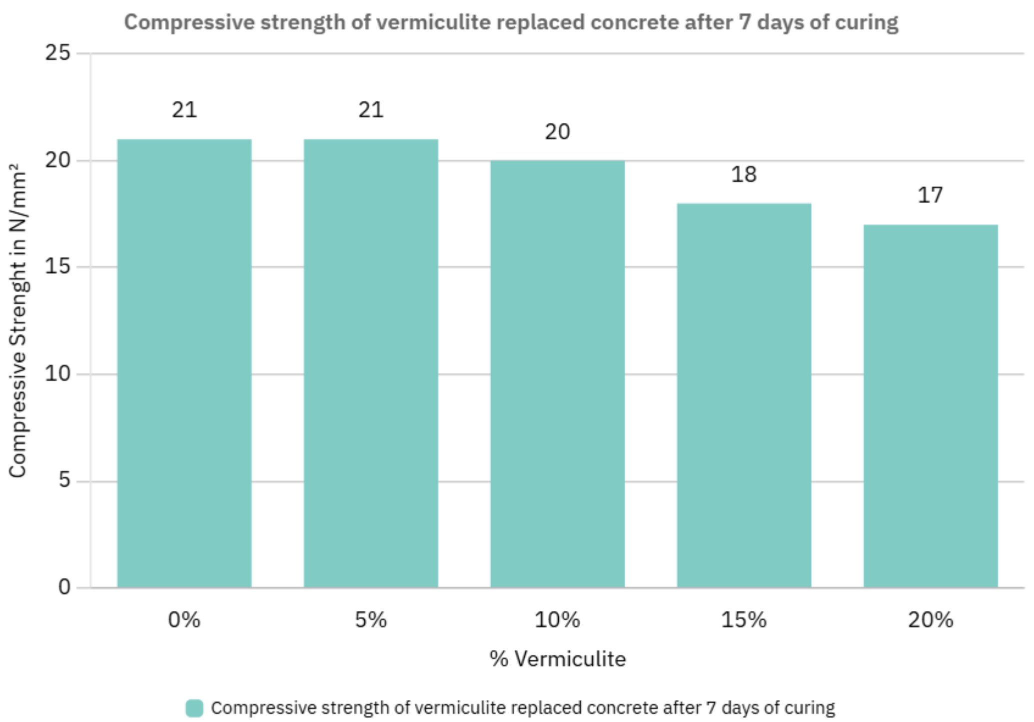


Figure 1

Compressive strength of vermiculite replaced concrete after 7 days of curing.

TABLE 3.3.6 Compressive strength of vermiculite replaced concrete after 14 days of curing

% of replacement	Average Compressive strength (N/mm²) (vermiculite)
0%	23
5%	22
10%	20.33
15%	19.66
20%	17.66

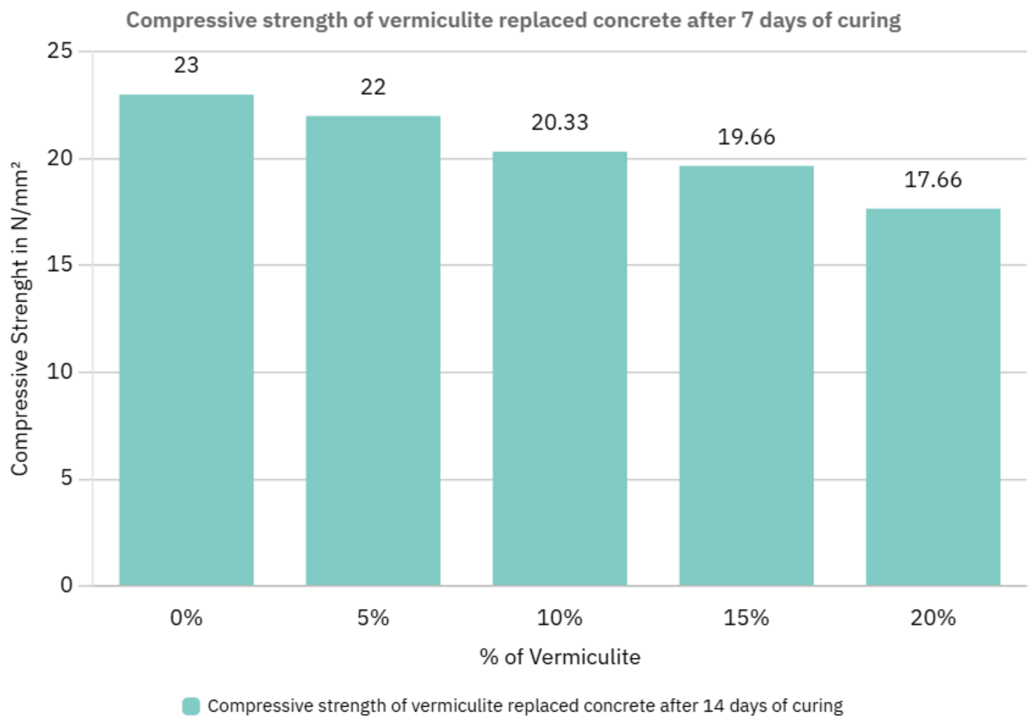


Figure 2

Compressive strength of vermiculite replaced concrete after 14 days of curing.

TABLE 3.3.7 Compressive strength of vermiculite replaced concrete after 28 days of curing

% of replacement	Average Compressive strength (N/mm²) (vermiculite)
0%	23.66
5%	23.5
10%	21
15%	19.66
20%	18.33

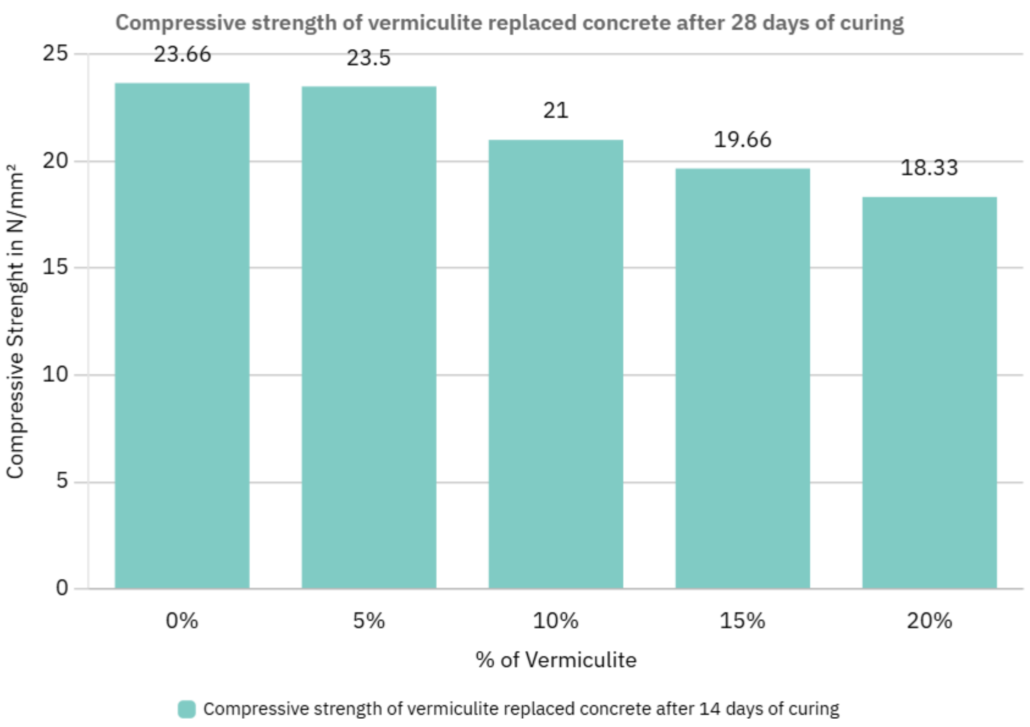


Figure 3

Compressive strength of vermiculite replaced concrete after 28 days of curing.

3.5.6 Density of vermiculite concrete

Table 8.4.1 shows the densities of vermiculite concrete at different replacement levels. When compared to PPC concrete, all the vermiculite replaced concretes are showing lesser densities.

TABLE 3.3.8 DENSITIES OF VERMICULITE CONCRETE IN DIFFERENT REPLACEMENTS 7 days.

Specimen No	Volume m^3	Bulk Density Dry= $\frac{Dry\ mass}{Volume}$ (Kg/m^3)
0%	0.003375	2533
5%	0.003375	2421.28
10%	0.003375	2315
15%	0.003375	2270
20%	0.003375	2259

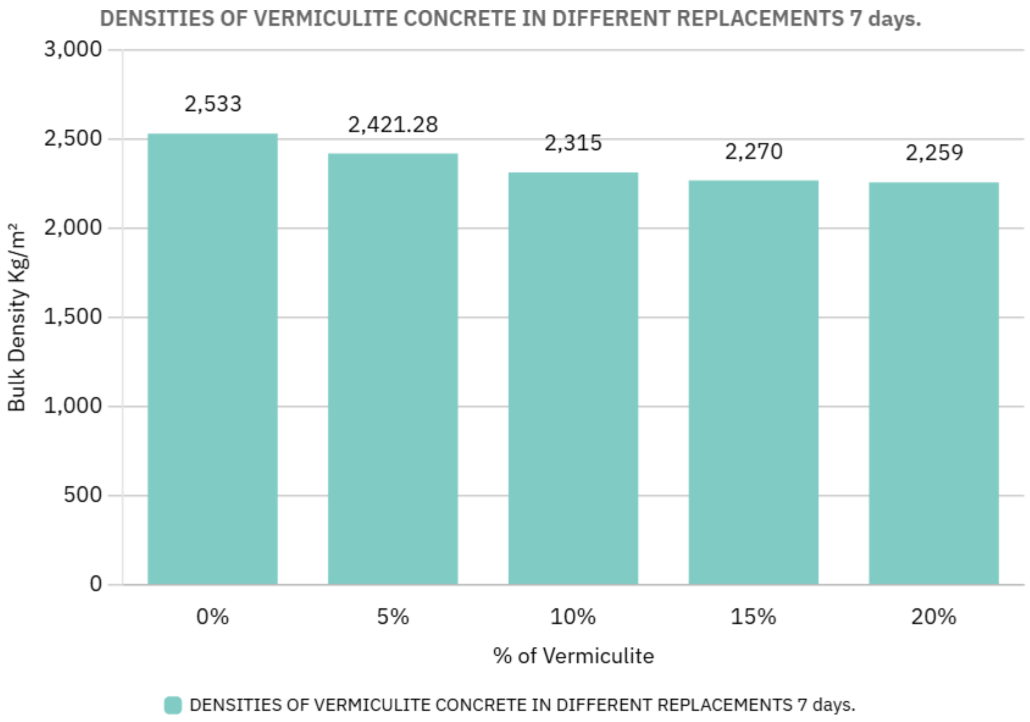


Figure 4

Densities of vermiculite concrete in different replacements 7 days

TABLE 3.3.9 DENSITIES OF VERMICULITE CONCRETE IN DIFFERENT REPLACEMENTS 14 days.

Specimen No	Volume m³	Bulk Density Dry=$\frac{Dry\ mass}{Volume}$ (Kg/m³)
0%	0.003375	2513.58
5%	0.003375	2346.667
10%	0.003375	2344.691
15%	0.003375	2270
20%	0.003375	2186.667

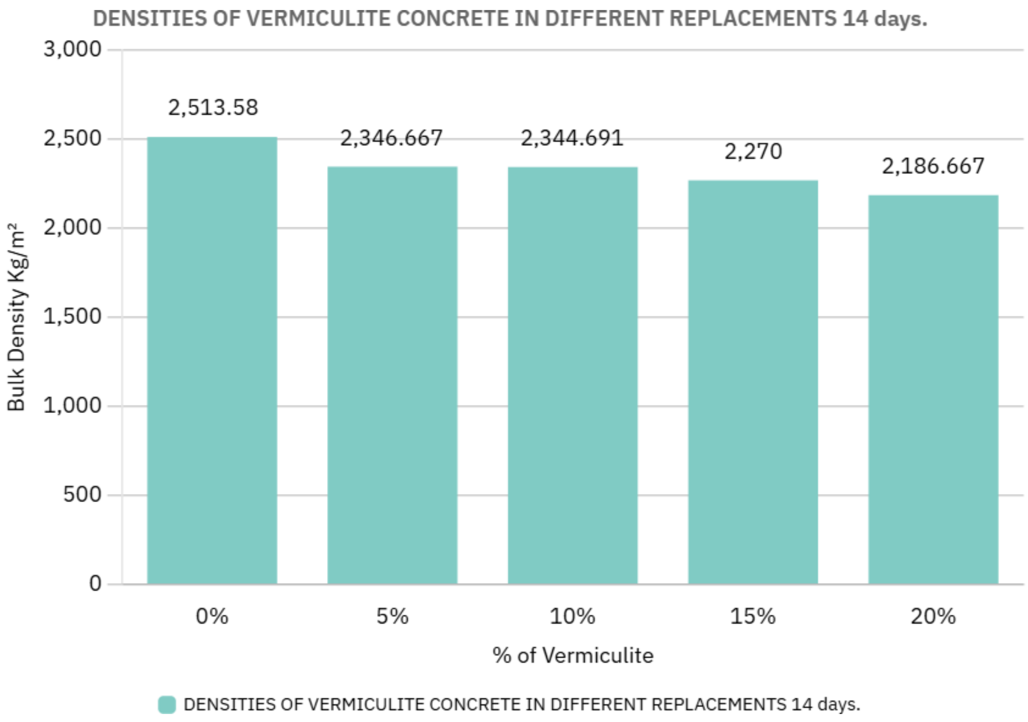


Figure 5

Densities of vermiculite concrete in different replacements 14 days

TABLE.3.3.10 DENSITIES OF VERMICULITE CONCRETE IN DIFFERENT REPLACEMENTS 28 days.

Specimen No	Volume m^3	Bulk Density Dry= $\frac{Dry\ mass}{Volume}$ (Kg/m^3)
0%	0.003375	2548.14
5%	0.003375	2412.84
10%	0.003375	2247.9
15%	0.003375	2188.642
20%	0.003375	2141.23

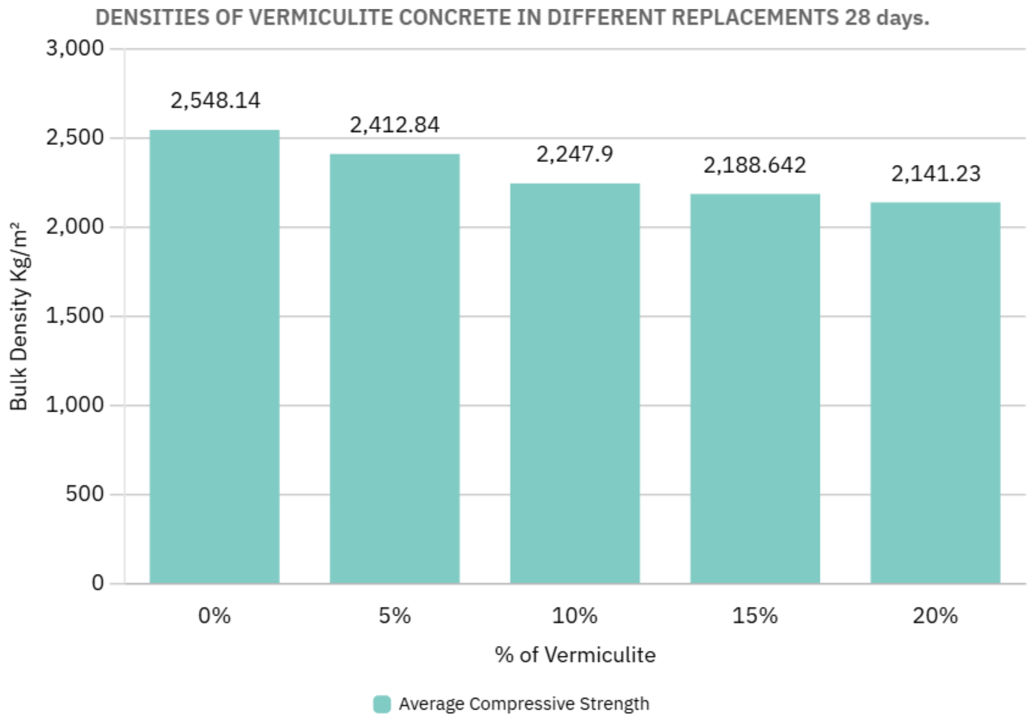


Figure 6

Densities of vermiculite concrete in different replacements 28 days.

4 RESULTS & DISCUSSIONS
1.1 COMPRESSIVE STRENGTH OF CONCRETE

ZERO PERCENTAGE OF VERMICULITE:

For 0% of vermiculite (28^{th} day test) = 24N/mm² - 24N/mm² - 23 N/mm² For 0% of vermiculite (14^{th} day test) = 23N/mm² - 23N/mm²-23N/mm² For 0% of vermiculite (07^{th} day test) = 21N/mm² - 21N/mm² - 21N / mm²

FIVE PERCENTAGE OF VERMICULITE:

For 5% of vermiculite (28^{th} day test) = 23.5 N/mm²- 23.5 N/mm² - 24 N/mm² For 5% of vermiculite (14^{th} day test) = 22 N/mm²-22.5 N/mm²-22 N/mm² For 5% of vermiculite (07^{th} day test) = 21 N/mm²-21 N/mm² - 21 N/mm²

TEN PERCENTAGE OF VERMICULITE:

For 10% of vermiculite (28^{th} day test) = 21 N/mm²-21 N/mm²-21 N/mm² For 10% of vermiculite (14^{th} day test) = 20 N/mm²-21 N/mm² - 20N /mm² For 10% of vermiculite (07^{th} day test) =20 N/mm²-20 N/mm² - 20 N/mm²

FIFTEEN PERCENTAGE OF VERMICULITE:

For 15% of vermiculite (28^{th} day test) = 20N / mm² - 19N / mm² - 20N / mm² For 15% of vermiculite (14^{th} day test) = 19N /mm² - 20N /mm² - 19N /mm² For 15% of vermiculite (07^{th} day test) =18 N/mm² - 18 N/mm²-18 N/mm²

TWENTY PERCENTAGE OF VERMICULITE:

For 20% of vermiculite (28^{th} day test) =19 N/mm² - 18 N/mm² - 18 N/mm² For 20% of vermiculite (14^{th} day test) =17 N/mm²- 18 N/mm²- 18 N/mm² For 20% of vermiculite (07^{th} day test) =17 N/mm²-17 N/mm² - 17 N/mm²

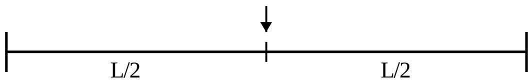
4.2 WEIGHT OR MASS OF CONCRETE

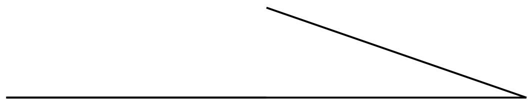
TABLE 4.1.1 Weight or Mass of Concrete

MINERALS	7TH DAY (KG)	14TH DAY (KG)	28TH DAY (KG)
VERMICULITE 0%	8.72 8.38 8.55	8.45 8.45 8.55	8.68 8.54 8.58
VERMICULITE 5%	7.96 8.44 8.12	7.76 7.91 8.09	8.09 8.32 8.02
VERMICULITE 10%	8.12 7.58 8.01	8.07 7.83 7.84	7.71 7.44 7.61
VERMICULITE 15%	7.68 7.65 7.75	7.87 7.81 7.54	7.27 7.51 7.38
VERMICULITE 20%	7.44 7.68 7.67	7.41 7.25 7.48	7.48 7.19 7.01

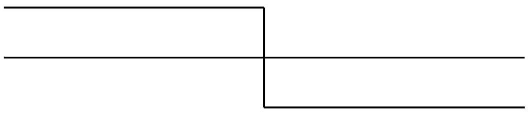
4.2 DESIGN OF BEAM FOR FLEXU
N OF BEAM FOR FLEXURE

Grade of Concrete	M30
Grade of steel	Fe 415
Length of Beam	1.00 m
Effective span Length	0.9 m
Breath of beam	150mm
Depth of Beam	200mm
Loading Method	Single Point Load (mid span)
End Condition	Simply Supported





B.M.D



S.F.D

We have to design a Beam failures occurs in the mode of flexure

$$\frac{x_u}{d - x_u} = \frac{\varepsilon_{cu}}{\varepsilon_s} \qquad (1)$$

$$\frac{x_u}{d} = \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_s} \qquad (2)$$

$$\varepsilon_{cu} = 0.0035 \qquad \text{(IS 456-2000 38.1(b))}$$

$$\varepsilon_s = 0.002 + \frac{0.87 f_y}{E_s} \qquad \text{(IS 456-2000 38.1(f))}$$

$$\varepsilon_s = 0.002 + \frac{0.87 \times 415}{2 \times 10^5} = 0.00366$$

$$\frac{x_u}{d} = \frac{0.0035}{0.0035 + 0.00366} = 0.479 \approx 0.48$$

$$\frac{x_{u,max}}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b d} = 0.48 \qquad \text{(IS 456-2000 Note 38.1)}$$

Clear cover	=	20 mm
Effective cover	=	(20 + 12/2) = 26 mm
Effective depth	=	200 − 24 = 174 mm
fck	=	30 MPa
b	=	150 mm

$$M_{u,\lim} = 0.36\frac{x_{u\max}}{d}\left[1 - 0.42\frac{x_{u\max}}{d}\right] bd^2 f_{ck} \quad \text{(IS 456-2000 Annex G 1.1(c))} \qquad (1)$$

$$= 19 \text{ kNm}$$

$$A_{st} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} b d^2}}\right] bd \qquad (2)$$

$$A_{st} = 240 \text{ mm}^2$$

Provided 2 nos of 10 mm dia bars.

$$A_{st} = 100 \text{ mm}^2$$

Moment carrying capacity of under reinforced section

$$M_u = 0.87 f_y A_{st} d\left(1 - \frac{A_{st} f_y}{bd f_{ck}}\right) \qquad (3)$$

$$M_u = 4.19 \text{ kNm} < M_{u,\lim}$$
$$A_{st} = 100 \text{ mm}^2$$

Hence provide 2 nos of 10 mm dia bars in tension and 2 nos of 8 mm dia bars as hanger bars.

The section should fail by flexure hence increase the shear resistance capacity of the beam.

$$M = \frac{Wl}{2} \qquad (6)$$

$$w = \frac{2M}{l}$$

$$w = 38 \text{ kN}$$

Jack load (w) = 38 kN

Design of shear Resistance (7)

A_{sv}= total cross sectional area of stirrup legs

Using 6mm φ (2 legged stirrup)

$$A_{sv} = \frac{2\pi \times 6^2}{4} = 56.55mm^2$$

$$s_v = \frac{0.87 \times 415 \times 56.55 \times 175}{13.125 \times 10^3} = 270mm$$

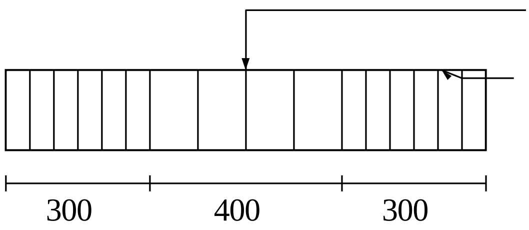
Provide maximum spacing of shear resistance

IS 456 – 26.5.1.5

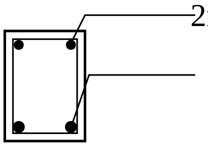
1. Shall not exceed 0.75d for vertical stirrups (131.25mm)
2. Spacing should not exceed 300mm

We choose 6mm φ 2 legged vertical stirrups at a 50 mm c/c distance from edges & 100mm c/c distance from center of the beam.

4.2.1 DETAILING OF BEAM



<u>LONGITUDINAL SECTION OF BEAM</u>



<u>CROSS SECTION OF BEAM</u>

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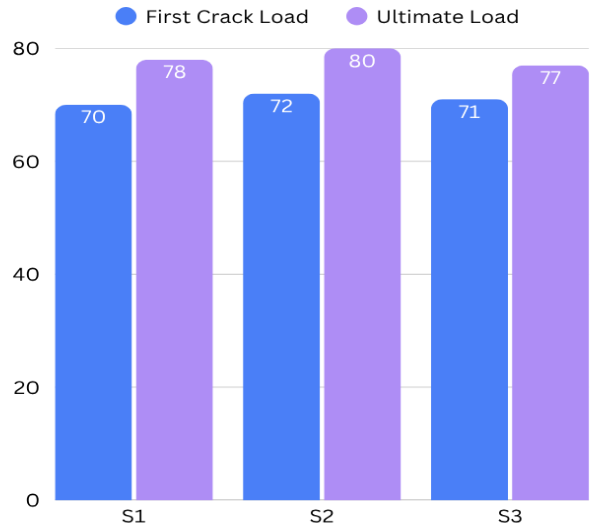
4.3.2 TEST RESULTS DISCUSSION

Table 4.1.1 Flexural Test Results for Beam Specimen with fully control Concrete

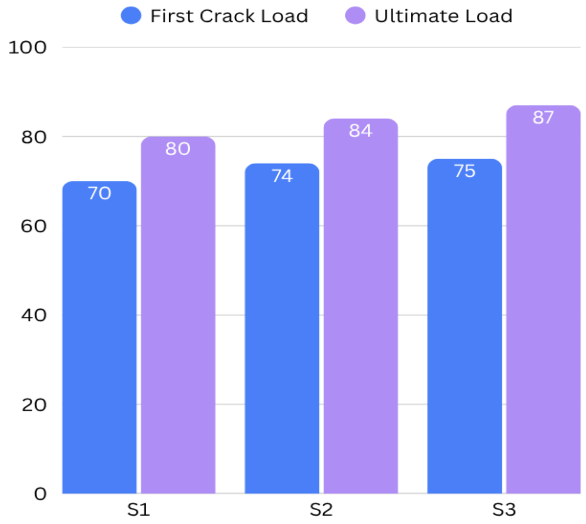
Specimen Details	First Crack Load(KN)	Ultimate Load(KN)	Deflection of Ultimate Load(KN)
S1	70	78	0.92
S2	72	80	0.94
S3	71	77	0.96



Comparison of First Crack Load and Ultimate Load(Flexure)

Table 4.1.2 Flexural Test Results for Beam Specimen with 5% of vermiculite

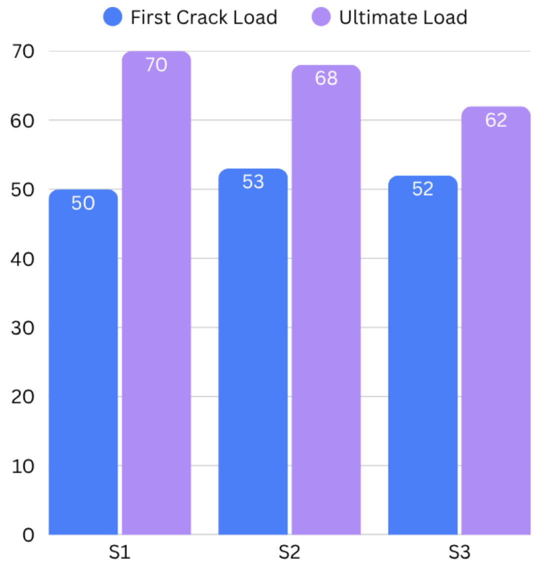
Specimen Details	First Crack Load(KN)	Ultimate Load(KN)	Deflection of Ultimate Load(KN)
S1	70	80	1.03
S2	74	84	1.08
S3	75	87	1.1



Comparison of First Crack Load and Ultimate Load(Flexure)

Table 4.1.3 Flexural Test Results for Beam Specimen with 10% of vermiculite

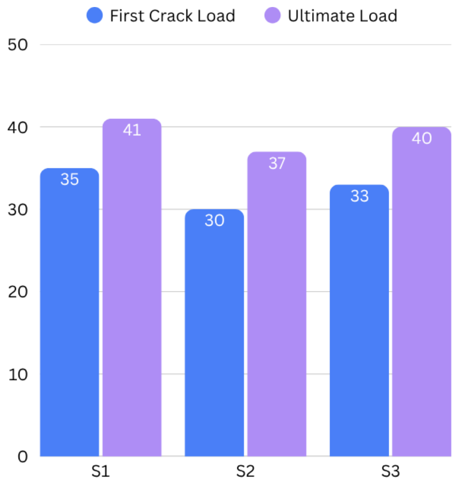
Specimen Details	First Crack Load(KN)	Ultimate Load(KN)	Deflection of Ultimate Load(KN)
S1	50	70	0.97
S2	53	68	0.96
S3	52	62	0.94



Comparison of First Crack Load and Ultimate Load(Flexure)

Table 4.1.4 Flexural Test Results for Beam Specimen with 15% of vermiculite

Specimen Details	First Crack Load(KN)	Ultimate Load(KN)	Deflection of Ultimate Load(KN)
S1	35	41	2.5
S2	30	37	2.8
S3	33	40	2.1



Comparison of First Crack Load and Ultimate Load(Flexure)

12. PHOTOS

CEMENT BAG

BLUE METALS

VERMICULITE

5. CONCLUSION

The following points are concluded from our project work.

- After 28 days curing, Vermiculite replaced concrete shows marginal decrease in compressive strength upto 20% when compared to control concrete.
- Workability is not good after 15% replacement of vermiculite.
- According to the result as we discussed upto 10% of vermiculite replacement may gives less deflection at ultimate load.
- While compared to 5%, 10%, 20% replacement of vermiculite replacement may carries a positive analysis result 5%.
- Both in the strength point of view it gives upto - 23.5N/mm2 (normal ppc

  -24N/mm2).
- Weight point of view - around 7-8 kg only (whereas normal ppc-leads to 8-9 kg).
- After experimental work - 5% replacement may carries a better result so it is best usage for further construction use.

5.1 SUGGESTIONS

Hereafter we suggest that,

- We have used PPC cement; we hope we will get more strength if we use ope than ppc..
- From our studies it is concluded that the replacement of 5% vermiculite shows good result.

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