International Journal for Modern Trends in Science and Technology
Volume 9, Issue 12, pages 45-69.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol9issue12.html
DOI: https://doi.org/10.46501/IJMTST0912004

AN EXPERIMENTAL STUDY OF EXPANDED POLYSTYRENE CONCRETE AS LIGHT WEIGHT MATERIAL CONTAINING STYROFOAM AS PARTIAL REPLACEMENT OF COARSE AGGRAGATE

Jagarapu Hemalatha[1] | K Jagan[2]

[1]PG Scholar, Department of Civil Engineering, Visakha Institute of Engineering and Technology, Visakhapatnam, India.
[2]Assistant Professor, Department of Civil Engineering, Visakha Institute of Engineering and Technology, Visakhapatnam, India.

To Cite this Article
Jagarapu Hemalatha and K Jagan. AN EXPERIMENTAL STUDY OF EXPANDED POLYSTYRENE CONCRETE AS LIGHT WEIGHT MATERIAL CONTAINING STYROFOAM AS PARTIAL REPLACEMENT OF COARSE AGGRAGATE, International Journal for Modern Trends in Science and Technology, 2023, 9(12), pages. 45-69. https://doi.org/10.46501/IJMTST0912004

Article Info
Received: 26November 2023; Accepted: 17 December 2023; Published: 26 December 2023.

ABSTRACT
Now days, the population growth is increasing significantly and the amount of waste materials are also increasing at the same time. Among a lot of waste materials, Styrofoam is widely used in food and manufacturing production equipment's as packaging materials because of its properties of absorbing vibration during handling and transportation process. Thus, Styrofoam can estimate as one of the waste materials that can lead to waste disposal crisis. Having light and buoyant properties, it is used as coarse aggregates in today's construction sites of today. The title of the project is "A Study of Expanded Polystyrene Concrete as Light Weight Material" and Styrofoam is used as a replacement of coarse aggregates in this project. 30 cubes of normal concrete, lightweight concrete with Styrofoam, and lightweight concrete with Styrofoam with addition of flyash in replacement of cement are prepared and compared the compressive strength on 28 days. The objective is to investigate the effect of expanded polystyrene Styrofoam (EPS) as a partial substitution of fine aggregate. To accommodate this objective, 9 different types of concrete mixture proportions were made. The first one is the normal concrete mixture without the addition of EPS. While the other 8 types of mixture were made with the additional 0%, 10%, 20%, 30%, 40%, 50% and 25% and 50% EPS concrete with 25% and 50% cement replacement with flyash. The properties of concrete investigated in this paper were compressive strength and ultrasonic pulse velocity (UPV) at the age of 28-day. The results indicate that there is a decrease in compressive strength and UPV with increasing amounts of

EPS and fly ash in concrete. From this research, it is found that adding Styrofoam can lead the decrease in strength of concrete but can give the buoyant lightweight concrete which is a common use in construction site in different places depending on the density and strength of lightweight concrete.

Keywords: **Styrofoam, Expanded Polystyrene, Light weight concrete, compressivestrength.**

INTRODUCTION

GENERAL

Concrete technology is growing and many advances and innovations have been made to cope with challenges of many construction aspects. Many productions of lightweight concrete had been designed and among them are by the use of lightweight aggregates and artificial aggregates such as fly ash and slag. Polystyrene is chosen due to its lightweight properties, with good energy absorbing characteristic and good thermal insulator leading mainly to non-structural applications. Lightweight concrete have been chosen by many designers and contractors due to cost favors especially in high-rise buildings and long-span bridges. Basically, lightweight concrete is produced by introducing air inside the concrete; either by using gassing and foaming agent or using lightweight aggregate such as natural aggregate (pumice, shale, slate) or industrial by-product (palm oil clinker, sinterized fly ash) or plastic granules (styrofoam or polymer materials).Lightweight aggregate (clinker, pumice, shale, slate etc.) and chemicals have been used by many researchers for the development of lightweight concrete.

- Lightweight concrete has remained a choice of designers due to the economy achieved in construction especially in the construction of highrise buildings.
- Lightweight concrete is prepared by either injecting a source of air within the concrete matrix in the form of a foaming agent, or by using lightweight aggregates.
- The use of lightweight concrete increases the resistance of concrete structures to more dead loads at a reduced weight of the overall structure, thus enhancing the functionality, architectural outlook and erection.
- Similarly, lager or longer precast concrete members can be prepared without adding to the overall weight of the concrete member.
- This results in a lesser amount of columns and pier elements in a construction system which is easier to place at the desired location with fewer joints.

In bridges, this may permit the use of an extensive bridge deck which can provide additional lanes.

BACKGROUND

Styrofoam is a prevalent material for the use in thermal insulation of buildings during construction. Apart from insulation, Styrofoam is widely used as packing of food materials in storing and for protecting goods from vibration forces during the transportation phase.

- It is treated as a waste product. The cell structure of Styrofoam consists of air up to 98%.
- This research study focuses on the performance of Styrofoam (packing material) as lightweight aggregate and its ability to reduce dead load without sacrificing the strength. Styrofoam particles were used to partially replace coarse aggregate.

Compressive strength and unit weight of normal density concrete (1:2:4) were used as benchmark for comparison with Styrofoam lightweight concrete. Expanded polystyrene beads are often used as the basis for packaging material. This leads to a large amount of waste material which is not biodegradable. This material could be granulated and used as a lightweight aggregate for concrete.

OBJECTIVE

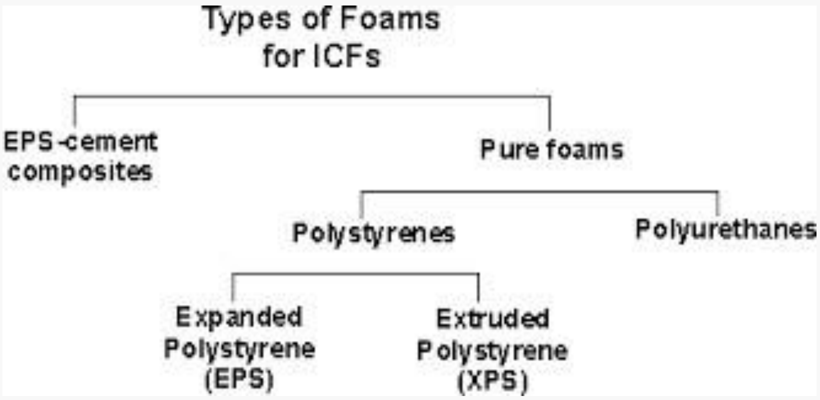
The objective of this paper is to prove the suitability of expanded polystyrene embedded in reinforced concrete on the basis of cost reduction, CFC Emission, more indoor comfort, least energy needs, thermal conductivity, Embodied energy, durability, sound insulation and earthquake resistance and to provide a prospective design methodology best suited as per Indian environment.

FOAMED CONCRETE

Polystyrene foams are good thermal insulators and are therefore often used as building insulation materials, such as in insulating concrete forms and structural insulated panel building systems. Grey polystyrene foam, incorporating graphite has superior insulation properties. They are also used for non-weight-bearing architectural structures (such as ornamental pillars). PS foams also exhibit good damping properties; therefore it is used widely in packaging. The trademark Styrofoam by Dow Chemical Company is informally used for all foamed polystyrene products, although strictly it

should only be used for 'extruded closed-cell' polystyrene foams made by Dow

Chemicals.



Types of Foams

Expanded polystyrene foam:

Expanded polystyrene (EPS) is a rigid and tough, closed-cell foam. It is usually white and made of pre-expanded polystyrene beads. EPS is used for many applications

e.g. trays, plates, bowls and fish boxes. Other uses include molded sheets for building insulation and packing material ("peanuts") for cushioning fragile items inside boxes. Sheets are commonly packaged as rigid panels (size 4 by 8 or 2 by 8 feet in the United States), which are also known as "bead-board". Due to its technical properties such as low weight, rigidity, and formability, EPS can be used in a wide range of different applications. Its market value is likely to rise to more than US$15 billion until 2020. Typical values of thermal conductivity range from 0.032 to 0.038 W/(m·K) depending on the density of the EPS board. The value of 0.038 W/(m·K) was obtained at 15 kg/m^3 while the value of 0.032 W/(m·K) was obtained at 40 kg/m^3 according to the data sheet of K-710 from StyroChem Finland. Adding fillers (graphites, aluminium, or carbons) has recently allowed the thermal conductivity of EPS to reach around 0.030–

0.034 (as low as 0.029) and as such has a grey/black color which distinguishes it from standard EPS. Several EPS producers have produced a variety of these increased thermal resistance EPS usage for this product in the UK & EU.

Extruded polystyrene foam:

Extruded polystyrene foam (XPS) consists of closed cells, offers improved surface roughness and higher stiffness and reduced thermal conductivity. The density range is about 28–45 kg/m^3. Extruded polystyrene material is also used in crafts and model building, in particular architectural models. Because of the extrusion manufacturing process, XPS does not require facers to maintain its thermal or physical property performance. Thus, it makes a more uniform substitute for corrugated cardboard. Thermal conductivity varies between 0.029 and 0.039 W/(m·K) depending on bearing strength/density and the average value is ~0.035 W/(m·K). Water vapour diffusion resistance (μ) of XPS is around 80–250 and so makes it more suitable to wetter environments than EPS.

MATERIALS USED:

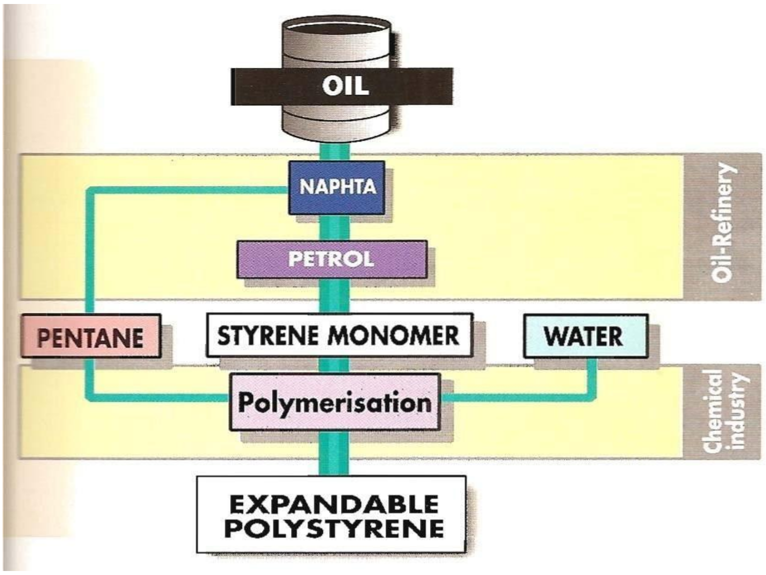
Standard Portland cement was used in all mixtures for this study, which met the requirement of fine and coarse aggregate were used that had been analyzed with sieve analysis. The coarse aggregate of size less than 20mm is used. The polystyrene used for the study (Figure 1) was in granular form, white in color, solid surface with diameter range between 2-2.5 mm, very light in weight with densities between 15 kg/m3-20 kg/m3. Mixing was done by using tap water.

Polystyrene Beads

Expanded Polystyrene Beads:

Polystyrene is a vinyl polymer. Structurally, it is a long hydrocarbon chain, with a phenyl group attached to every other carbon atom. Polystyrene is produced by free radical vinyl polymerization, from the monomer styrene. Expandable polystyrene (EPS) meanwhile is polystyrene in raw beads being steam-heated, causing it to expand. Polystyrene has been used mainly in cold countries to make concrete blocks for residential purposes. Polystyrene is commonly injection molded, vacuum formed, or extruded, while expanded polystyrene is either extruded or molded in a special process. Polystyrene copolymers are also produced; these contain one or more other monomers in addition to styrene. In recent years the expanded polystyrene composites with cellulose and starch have also been produced. Polystyrene is used in some polymer- bonded explosives (PBX).

Manufacture of Expanded Polystyrene



Physical Properties

EPS has been a material of choice for over half a century because of its technical versatility, performance and cost effectiveness. It is widely used in many everyday applications where its light weight, strength, durability, thermal insulation and shock absorption characteristics provide economic, high performance products.

Light Weight:

EPS is an extremely lightweight material which is not surprising considering it is comprised of ~98% air. This characteristic makes it ideal for use in packaging as it does not significantly add to the weight of the total product thereby reducing transportation costs. Energy consumption for transport fuel is also reduced and vehicle emissions minimized – all contributing to lower global warming.

Durability:

The exceptional durability of EPS makes it an effective and reliable protective packaging for a wide range of goods. The cellular structure of EPS makes it dimensionally stable and therefore does not deteriorate with age. EPS is also odourless and non-toxic.

Moisture Resistance:

EPS is a closed cell material and does not readily absorb water. There is no loss of strength in damp conditions, making EPS ideal for cool-chain products. The material is moisture resistant, so the highest hygiene requirements are met. The ability of EPS to resist moisture also lends itself for use in fishing floats and marina buoys. Even when subjected to prolonged saturation in water, EPS will still maintain its shape, size, structure and physical appearance with only a slight reduction to its thermal performance.

Thermal Efficiency:

The superior thermal efficiency of EPS makes it ideal for packaging any product that is sensitive to temperature change. Products enclosed in EPS containers can be maintained for long periods at temperature above or below ambient conditions and can be protected from sudden temperature changes that can occur in the transport through different climatic zones. Examples include fresh produce and seafood as well as pharmaceutical and medical products.

Shock Absorption:

EPS exhibits excellent shock absorbing characteristics making it the first choice forpackaging of a wide range of products including appliances, electronic products, computers and chemicals.

Versatility:

EPS can be manufactured to almost any shape or size, or it can be easily cut and shaped when required to suit any application. EPS is also produced in a wide range of densities providing a varying range of physical properties. These are matched to the various applications where the material is used to optimise its performance. In addition, EPS is also compatible with a wide variety of materials.

Ease of Use:

For building and construction applications, EPS is considered to be one of the easiestmaterials to install on site. It is normally supplied in sheet form however can also be molded into shapes or in large blocks.

Mechanical Properties:

The mechanical properties of EPS foam depend primarily on density. Generally, strength characteristics increase with density; however the cushioning characteristics of EPS foam packaging are affected by the geometry of the molded part and, to a lesser extent, by bead size and processing conditions, as well as density. This by simple processing changes, without the need to redesign or retool. For shock cushioning, the EPS packaging industry has developed typical cushioning curves for use by designers of EPS transport packaging. Shock cushioning properties of EPS are not significantly affected by change in temperature.

Dimensional Stability:

Dimensional stability is another important characteristic of EPS foam. It represents the ability of a material to retain its original shape or size in varying environmental conditions. Different plastic polymers vary in their reaction to the conditions of use and exposure to changes in temperature and/or relative humidity. Some shrink, some expand and some are unaffected. EPS offers exceptional dimensional stability, remaining virtually unaffected within a wide range of ambient factors. The maximum dimensional change of EPS foam can be expected to be less than 2%.

Thermal Insulation:

For construction insulation applications the polystyrene foam industry has developed for Rigid Cellular Polystyrene Thermal Insulation. This standard addresses the physical properties and performance characteristics of EPS foam as it relates to thermal insulation in construction applications.

Water Absorption and Vapor Transmission:

The cellular structure of EPS is essentially water resistant and provides zero capillarity. However, EPS may absorb moisture when it is completely immersed, due to the fine interstitial channels between the molded beads. While molded EPS is nearly impervious to liquid water, it is moderately permeable to water vapor under pressure differentials. Vapor permeability is determined by both density and thickness. Generally, neither water nor water vapors affect the mechanical properties of EPS.

Water absorption of polystyrene foams:

Although it is closed-cell foam, both expanded and extruded polystyrene are not entirely waterproof or vapor proof. In expanded polystyrene there are interstitial gaps between the expanded closed-cell pellets that form an open network of channels between the bonded pellets, and this network of gaps can become filled with liquid water. If the water freezes into ice, it expands and can cause polystyrene pellets to break off from the foam. Extruded polystyrene is also permeable by water molecules and cannot be considered a vapor barrier.

Water logging commonly occurs over a long period of time in polystyrene foams that are constantly exposed to high humidity or are continuously immersed in water, such as in hot tub covers, in floating docks, as supplemental flotation under boat seats, and for below-grade exterior building insulation constantly exposed to groundwater. Typically an exterior vapor barrier such as impermeable plastic sheeting or a sprayed-on coating is necessary to prevent saturation

Chemical Resistance:

Water and aqueous solutions of saltsand alkalis do not affect expanded polystyrene. Most organic solvents are not compatible with EPS. This should be taken into consideration when selecting adhesives, labels and coatings for direct application to the product. All substances of unknown composition should be tested for compatibility. Accelerated testing may be carried out by exposing molded polystyrene to the substance at 120 – 140 F. UV radiation has a slight effect on molded polystyrene. It causes superficial yellowing and friability, but does not otherwise effect its physical properties.

Electrical Properties:

The volume resistively of molded polystyrene within the 1.25 – 2.5 pcf density range, conditioned at 73 F and 50% r.h. is 4 x 1013 ohm-cm. The dielectric strength is approximately 2KV/mm. At frequencies up to 400 MHz, the permittivity is 1.02 – 1.04 with a loss factor less than 5 x 10–4 and less than 3 x 10–5 at 400 MHz.

Ordinary Portland Cement

Cement can be defined as the bonding material having cohesive & adhesive properties which makes it capable to unite the different construction materials and form the compacted assembly. Ordinary/Normal Portland cement is one of the most widely used types of Portland cement.

Applications

1. High-rise Buildings, Residential, Commercial & Industrial Complexes

»Roads, runways, bridges and flyovers.
»Defense Construction.
»For heavy defense structures like Bunkers
»Pre-stressed concrete structures

Physical properties:

TABLE-1.1 BIS SPECIFICATIONS AND SDCC NORMS OF 53 GRADE OPC

Sl.No	**Description**	**Unit**	**Req. as per IS-12269- 1987**	**SDCC Norms**
A) CHEMICAL COMPOSITION				
1.	Insoluble Residues(IR)	%	3.0 Max	2.0 Max.
2.	Magnesium Oxide(MgO)	%	6.0 Max	2.5 Max.
3.	Sulphuric Anhydride(SO3)	%	2.5 Max when C3A<5 & 3.0 Max when C3A>5	2.75 Max.
4.	Loss on Ignition(LOI)	%	4.0 Max	3 Max.
5.	Lime Saturation Factor (LSF)	%	0.80-1.02	0.90Min.
6.	Alumina Iron ratio (A/F)	%	0.66 Min.	1.10 Min.
7.	Chloride (CI-)	%	0.10 Max.	0.05 Max
B) PHYSICAL PROPERTIES				
1.	Specific Surface	m2/kg	225 Min.	280 Min.
2.	Soundness (Expansion)			
	a) By Le-Chatelier	Mm	10.0 Max.	3.0 Max.
	b) By Autoclave	%	0.8 Max.	0.2 Max
3.	Setting Time			
	a) Initial Set	Minute	30 Min.	70 Min.
	b) Final Set	Minute	600 Max.	250 Max.
4.	Compressive Strength			

	a) 3 days	MPa	27 Min.	35 Min.
	b) 7 days	MPa	37 Min.	45 Min.
	c) 28 days	MPa	53 Min.	58 Min.

Fine Aggregate (Sand)

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. **Sand** can also refer to a textural class of soil or soil type; i.e. a soil containing more than 85% sand-sized particles (by mass).

The composition of sand varies, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non- tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz. The second most common type of sand is calcium carbonate, for example aragonite, which has mostly been created, over the past half billion years, by various forms of life, like coral and shellfish. It is, for example, the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years like the Caribbean.

Properties of sand:

- Roundness and Sphericity.
- Sand is ubiquitous. It makes up most beach and river deposits.
- Sand is concentrated by selective transport.
- Sand is left at beaches as the finer clay particles are washed out to sea.
- A medium sized river takes about a million years to transport a sand grain 100 miles downstream.
- Transport does not do much to change the roundness and sphericity of the sand grains.
- Work by Kuenen (1960) has shown that the rounding of sand grains is due almost entirely to wind abrasion and that the sphericity of sand grains is inherited from their original crystal structure

Coarse Aggregrate:

Coarse aggregate shall consist of naturally occurring materials such as gravel, or resulting from the crushing of parent rock, to include natural rock, slags, expanded clays and shales (lightweight aggregates) and other approved inert materials with similar characteristics, having hard, strong, durable particles, conforming to the specific requirements of this Section. Coarse aggregate for use in nonstructural concrete applications or hot bituminous mixtures may also consist of reclaimed Portland cement concrete meeting the requirements of 901-5. Washing of this material will not be required if the requirements of 901-1.2 for maximum percent of material passing the No. 200 sieve can be met without washing

Properties

Characteristics controlled by porosityDensity:

Apparent specific density: Density of the material including the internal pores.

Bulk density (dry-rodded unit weight) weight of the aggregate that would fill a unit volume: affects the following concrete behavior: mix design, workability, and unit weight.

Absorption and surface moisture:

Affects the following concrete behavior:

Mix-design,Soundness,

Strength/ abrasion resistance:

Soundness:

Aggregate is considered unsound when volume changes in the aggregate induced by weather such as alternate cycles of wetting and drying or freezing and thawing result in concrete deterioration.

Depends on: porosity, flaws and contaminants

Pumice- (10% absorption) - no problem with freezing and thawing Limestone- breaks use smaller aggregate (critical size)

Particle size

Size: Affects the following concrete properties: water demand, cement content,microcracking. Grading

Depends on: proportions of coarse and fine aggregateAffects: paste content (cost economy), workability.

Water:

A general understanding of the role of water in the process of cement hydration is important. The cement in the concrete needs water to hydrate and form Calcium- Silicate-Hydrate (C-S-H) which is the glue that holds the concrete together. The water is chemically bound (consumed) during the reaction with the cement at approximately 25 pounds of water to every 100 pounds of cement. Therefore, it could be said CEMEX USA - Technical Bulletin 9.1 2 that a water to cementitious materials ratio (w/cm) of 0.25 is needed for the C-S-H and hydration products to be formed. That, however, is not all of the water that is needed. There is additional water that becomes physically bound between the cement hydrates. In order to have enough water to possibly enable complete hydration of the cement, approximately 20 pounds of water to every 100 pounds of cement is necessary. Combined, this equates to approximately 45 pounds resulting in a w/cm of 0.45. It should be noted that a concrete rarely gets the benefit of complete cement hydration typically because of the lack of physical access to the inner unhydrated cement particles and also due to lack the minimum required curing thatwould be needed.

A properly proportioned concrete mix should possess these qualities:

1. Acceptable workability of the freshly mixed concrete.
2. Durability, strength, and uniform appearance of the hardened concrete.
3. Economy.

Characteristics of EPSC:

Permeation characteristics:-

Water absorption: Water absorption of foam concrete decreases with a reduction in density, which is attributed to lower paste volume phase and thus to the lower capillary pore volume. The oxygen and water vapour permeability of foam concrete have been observed to increase with increasing porosity and fly ash content.

Sorptivity: The moisture transport phenomenon in porous materials has been defined by an easily measurable property called sorptivity (absorbing and transmitting water bycapillarity), which is based on unsaturated flow theory.

Sorptivity of foam concrete is reported to be lower than the corresponding base mix and the values reduce with an increase in foam volume.

Resistance to aggressive environment:

Foam concrete mixture designed at low density taking into consideration of depth of initial penetration, absorption and absorption rate, provided good freeze-thaw resistance. Sulphate resistance of foam concrete reveals that foam concrete has good resistance to aggressive chemical attack.

Functional characteristics:

- Fire resistance
- Thermal insulation

Thermal insulation Foam concrete has excellent thermal insulating properties due to its cellular microstructure. The thermal conductivity of foam concrete of density 1000 kg/m3 is reported to be one-sixth the value of typical cement–sand mortar.

Fire resistance

Foam concrete is extremely fire resistant and well suited to applications where fire is a risk. Test have shown that in addition to prolonged fire protection, the application of intense heat, such as a high energy flame held close to the surface, does not cause the concrete to spall or explode as is the case with normal dense weight concrete.

APPLICATIONS OF EPS CONCRETE:

Building Blocks: Blocks and panels can be made for partition and load bearing walls. They can be made with almost any dimensions.

Floor Screed: EPS concrete can be used for floor screeds, creating a flat surface on uneven ground and raising floor levels.

Roof Insulation: EPS Concrete is used extensively for roof insulation and for making a slope on flat roofs. It has good thermal insulation properties and because it is lightweight foamed concrete does not impose a large loading on the building.

Road Sub-Base: EPS Concrete is being used road sub base on a bridge. Foamedconcrete is lightweight so that the loading imposed on the bridge is minimized.

Non structural members such as:

- Interior wall panels (non-load bearing walls), False ceilings
- Aesthetic decors
- Sun shades, Custom made wardrobes, etc.

LITERATURE STUDY

Polystyrene aggregate concrete is one of many lightweight, low strength materials with good energy absorbing characteristics. It is well known for its good thermal and acoustic insulation properties leading mainly to non-structural applications including precast roof and wall panels and lightweight infill blocks (**Parton, 1982**). It has also been considered for use as a core material in sandwich panels, beams, and slabs (Parton, 1982), as a sub-base material for road pavements (**Hanna, 1978**) and also in floating marine structures (**Bagon and Yannas, 1976**). In Japan, it has been used in the construction of sea beds and sea fences (**Yoshino et al., 1980**).

A study conducted by **Perry eta.l (1991)** on mix details and material behavior of polystyrene aggregate concrete proved that strength and density are controlled by varying mix proportions. **Ravindrarajah et al. (1993)** reported their study on the properties of hardened concrete containing polystyrene beads. Their results showed that the strength, stiffness and chemical resistance of polystyrene aggregate concrete of a constant density are affected by the water to cement ratio.

Another study **by Bischoff et al. (1991)** found that polystyrene aggregate concrete is useful to absorb energy and to reduce contact loading loads during hard impact at low velocities. Work was also carried out by the Cement and Concrete Association of New Zealand in 1991 which examined the strengths and some drying shrinkages of recycled EPS concrete. The study highlighted difficulties in compaction and finishing of concrete with densities below 1000kg/m3.

Hamdan (2000) in a study reports that the use of polystyrene beads as lightweight aggregates shows lightweight property that highlights the use of polystyrene aggregate concrete in non-structural applications.

The **Canadian Foundation Engineering Manual 3rd Edition** has **specific recommendations** where structures have a greater risk of frost heave and in certain cases these structures must be separated from the primary structure. Buildings without basements are often supported on cast-in-place concrete piles with perimeter grade beams. Since foam insulation has a high compressive strength it cannot be used as a void former to absorb heave movement. A proper minimum thickness of well drained and well compacted clean granular fill as well as foam insulation is required under grade beams and it is a common practice to make reinforcing in grade beams symmetrical top and bottom such that some uplift load can be tolerated without risk of cracking.

Sabaa and Ravindrarajah studied engineering properties of polystyrene (PS) aggregate concrete by partially replacing natural coarse aggregate with equal volume of the chemically coated polystyrene at the levels of 30, 50 and 70%. They found that compressive strength, unit weight and modulus of elasticity decreased and drying shrinkage and creep increased with increasing PS aggregate replacement in concrete.

Babu investigated the behaviour of light weight expanded polystyrene concrete containing silica fume and found that the rate of strength development increased and the total absorption values decreased with increasing in replacement levels of silica fume in concrete. It was also found that the strength of EPS concrete marginally increased as EPS bead size decreased and increased as the natural coarse aggregate size in concrete increased.

The **SaradhiBabu et al.** study covers the use of expanded polystyrene (EPS) beads as light weight aggregate, both in concrete and mortar. The mechanical properties of EPS concretes containing fly ash were compared to the results of concretes containing Portland cement alone as the binder. The compressive strength of the EPS concretes containing fly ash show a continuous gain even up to 90 days, unlike that reported for Portland cement in literature. It was also found that the failure of these concretes both in compression and split tension was gradual as was observed for the concretes containing plastic shredded aggregates. This study tested mixtures withdensities as low as 600kg/m.

The results of compressive tests in the **Miled et al.** investigation confirmed the presence of a particle size effect on the EPS concrete compressive strength since it was observed that the smaller the EPS bead size, the greater the concrete compressive strength, for the same concrete porosity.

Most research on EPS concretes as mentioned above has shown a decrease in the durability performance and the engineering properties of concrete with increasing the amount of polystyrene aggregate in mixtures and an increase in strength with smaller EPS bead size in concrete. The studies on EPS concretes reviewed above have also shown that mixtures produced using the ordinary vibration method will lead to a large number of particles floating upward and serious concrete segregation, resulting in EPS lightweight aggregate concrete with reducing its various performances. This is due to the ultra-light EPS particles and being quite weak. A great deal of research has used super plasticisers and fly ash to increase the workability of the concrete. Additives like these may not be readily available in developing countries. An abundant natural resource in most countries should be tested as an alternative material to improve the resistance to segregation of EPS in concrete.

Use Styrofoam in concrete material by utilizing waste concrete can reduce construction costs, slowing the onset of the heat of hydration, lower density of concrete, and reduce the work load earthquakes is smaller due to heavy concrete structures is reduced. That in the end the exploitation of natural materials such as sand, gravel, and cement for building materials can be reduced. Motivation to investigate the performance of sandwich beams of normal and lightweight concrete is to design structural elements that utilize the most advantageous properties of two different concrete quality and they are in one section. Sandwich beams are used in applications requiring high bending stiffness and strength combined low weight.Studies on the use of truss system reinforcement of structural elements have been conducted by several researchers such as **Salmon et. al**. which uses steel trusses on the panel to reduce deflection shell.

Deshpande et.al. conducted experimental sandwich beam, which consists of a triangular truss core face-sheets, which have been casted with aluminium-silicon alloy and silicon in brass to get macroscopic effective stiffness and strength sheet face-sheets and tetrahedral core. **Liu et.al.** studied a multiparameter optimization procedure on the panel Ultra-lightweight truss-core sandwich. Optimization of improving structural performance of each panel in the case of multiple loading and minimize structural weight simultaneously.

Kabir developed a method to investigate the mechanical characteristics of the 3D sandwich wall panel in shear and flexural static load, in order to understand the structural components.

Studies on the use of reinforcement frame system on structural elements have been conducted by several researchers such as **Salmon and Einea**, which uses steel trusses on the panel to reduce deflection shell. **Deshpande and Fleck**, conducted experimental beam sandwich, which consists of a triangular truss core face-sheets, whichhave been printed with aluminium-silicon alloy and silicon in brass to get macroscopic effective stiffness and strength of face-sheets and tetrahedral core. **Kocher Watson, Gomez and Birman,** presents a theoretical approach to study several issues related to the design of sandwich structures with a polymer frame reinforced with hollow core using a simple analytical model that describes the contribution to the stability of the structure is hollow at the core.

In general, the research related to the utilization of waste styrofoam for use in beam structural elements for purposes of efficiency of use of natural materials in concrete construction and application of environmentally technological knowledge. A series of experimental testing have been performed. The concrete that filled with the 30% Styrofoam grains is named with Styrofoam Filled Concrete (SFC-30).

Park and Chisholm use polystyrene as fine aggregate and has a less specific gravity ranges from 520 to 1040 kg/m3 has a very low compressive strength, which is in the range 0.7 MPa to 6.7 MPa. These results are far from the minimum requirement of concrete to be used as structural concrete. The need for water in the mixture is lower than design mix; the excess water will cause segregation of the cement paste. Concrete mould compaction process cannot be performed conventionally for material that is light enough. Compaction process into the mould is done layer by layer by using the pressure of human hands. Compaction method using a vibrator is also not recommended in the manufacture of lightweight concrete mixtures with polystyrene aggregate. Park and Chisholm also showed that the mixture with a cement content of 1000 kg/m3 are able to produce cement paste enough to wrap the aggregate and produce a good surface.

Meanwhile, **Kuhail** showed approximately the same results, that the more the content of polystyrene in the mixture it will reduce the compressive strength of concrete. By using the ratio of polystyrene: sand = 5: 1 and the cement content of 600 kg/m3 can generate compressive strength of 15 MPa and density of 1200 kg/m3, so it can be said that the concrete has been produced can be used as a concrete structural and non-structural concrete.

Momtazi et.al did research on the durability of lightweight concrete epoxy polystyrene in an environment with high salinity. The results of Momtazi mention that within 210 days, the presence of polystyrene epoxy material in the concrete mix at high salinity environments can provide fairly good protection against the risk of corrosion of reinforcing steel, however, the nature - the mechanical properties of concrete decreased slightly due to the presence of epoxy polystyrene.

Another study conducted by **Babu et.al** and **Fonteboa** and **Abella** the two researchers are using pure EPS beads and recycled EPS beads are mixed with silica fume as the building blocks of concrete mixes. The results showed that the concrete mixture obtained has a specific gravity of between 1500 to 2000 kg/m3 with compressive strength ranging from 10 to 21 MPa. Silica Fume able to increase the initial compressive strength of concrete mix at the age of 7 days.

Bhikshma et.al. conduct an experimental study on RC Beams, which has been damaged and repaired with epoxy resin. From their study, it has been concluded that material comes from epoxy can be used to repair the damaged structures, cheaper thanto reconstruct the structure.

Another study conducted by **Bakhtiyari et.al** investigate the influence of expanded polystyrene as a formwork on fire resistance of self compacting concrete.

Several researchers studied the structural, physical and mechanical behaviour of polystyrene concrete. They avoided vibration compaction during the manufacturing of (PC) and compacted their mixes by hand tamping to minimize the segregation of polystyrene beads because of its low density. The main aim of this investigation is to use polystyrene beads to produce (SC-PC) which is a special type of concrete mixture characterized by high resistance to segregation that can be cast without compaction or vibration , because it becomes levelled and compacted under its self-weight .

Sussman concluded that the mechanical properties of (PC) increase with the increase of its density and these properties are controlled by the water to cement ratio. **Maura** also produced (PC) with densities between (220-460) kg/m3 and compressive strength between (0.7-2.3)MPa, while modulus of rapture was between (0.30.36)MPa.

Ismail studied the properties of hardened concrete bricks containing polystyrene beads and he found that (PC) is very prone to segregate where placing and compacting can be quite difficult using vibratory compaction techniques .Also he found that the (PC)bricks with densities less than 1800kg/m3 have very low strength which can be used as a non-load bearing internal wall while the (PC) with density of (1646)kg/m3 have compressive strength of (14MPa) which is suitable to use as a load bearing internal wall . **Kuhail** studied the characteristics of (PC) and he proved that the proposed mix is very reliable giving strength of up to 200kg/cm2 with low density. Also he found very high mix workability at a very low water/cement ratio (down to 0.35).

Annually, approximately 600 million tons of rice paddy is produced (**Chandrasekhar et al., 2003**). For every 1000 kg of paddy milled, about 200 kg of husk is produced, and when this husk is burnt, about 40 kg of RHA is generated (Cook, 1986). RHA has 90–95% amorphous silica (**Metha, 1992**). It is highly porous, lightweight and has a high surface area (**Della et al., 2002**). Many previous researches showed that RHA can be used successfully in other building materials such as bricks and blocks without any degradation in the quality of products (**Nasly and Yassin, 2009; Rahman, 1988**).

An intensive literature survey on light weight concrete has been carried out to seek references to the use of polystyrene in concrete mixes, more than 3000 websites were visited over the internet, and nothing was directly related to the topic of this paper. Accordingly extensive work is needed to explore all chemical, physical and structural properties. An attempt has been made to explore, provisionally, the structural and physical behaviour, advantages and disadvantages of Polystyrene concrete.

EXPERIMENTAL INVESTIGATION

COMPRESSION TEST

The investigation is carried out to study the Compressive Strength, Split Tensile Strength and Flexural Strength of Bacterial Concrete. A total of 20 sets of cubes, each M20 and M60 grade concrete, are cast and tested to study the Compressive Strength under axial compression a total of 6 sets of cylinders, each M20 and M60 grade concrete, are cast and tested to study the Split Tensile Strength and a total of 6 sets of prisms, each M20 and M60 grade concrete, are cast and tested to study the Flexural Strength of concrete.

Specimen Preparation

Ordinary Grade Concrete (M20) and High Strength Grade Concrete (M60) mixes are designed. Cubes of 100mm x 100mm x 100mm are made as per IS: 516- 1999 along with Cylinders of 150mm x 300mm and prisms of 100mm x 100mm x 500mm are cast. The cubes, cylinders and prisms are cast using with bacteria and without bacteria. After casting, the specimens are demoulded after 24 hours and immediately submerged in clean fresh water of the curing tank. After the completion of curing period the specimens are taken and kept under shade before testing.

Testing Procedure

After the required period of curing the cube specimens are removed from the curing tank and cleaned. A set of cubes are tested for Compressive Strength at 7, 14, 28, 60 and 90 days , cylinders are tested for Split Tensile Strength at 28, 60 and 90 days and prisms are tested for Flexural Strength at 28, 60 and 90 days.

NDT tests

Studies on Estimating Compressive Strength of Concrete through NonDestructive Techniques

Rebound Hammer Test

Description of Schmidt's Rebound Hammer TestOBJECTS

The rebound hammer method could be used for :

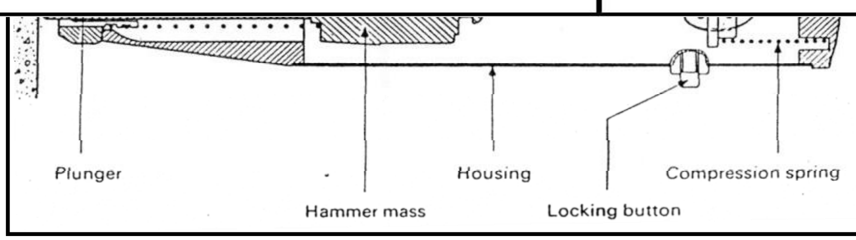
- Assessing the compressive strength of concrete with the help of suitable co-relations between rebound index and compressive strength
- Assessing the uniformity of the concrete
- Assessing the quality of concrete in relation to the standard requirements
- Assessing the quality of one element of concrete in relation to another.[1]

Principle of test: The test is based on the principle that the rebound of an elastic mass depends on the hardness of the surface upon which it impinges. When the plunger of the rebound hammer pressed against the surface of the concrete, the spring controlled mass rebounds and the extent of such rebound depend upon the surface hardness of concrete. The surface hardness and therefore the rebound is taken to be relation to the compressive strength of concrete. The rebound is read off along a graduated scale and is designated as the rebound number or rebound index.

Basic Features of Rebound Hammer

The impact energy required for rebound hammer for different applications is givenbelow –

Sr. No.	Application	Approximate impact energy required for the rebound hammers (N-m)
1.	For testing normal weight concrete	2.25
2.	For light weight concrete or small and impact sensitive part of concrete	0.75
3.	For testing mass concrete i.e. in roads, airfield pavements and hydraulic structures	30.00

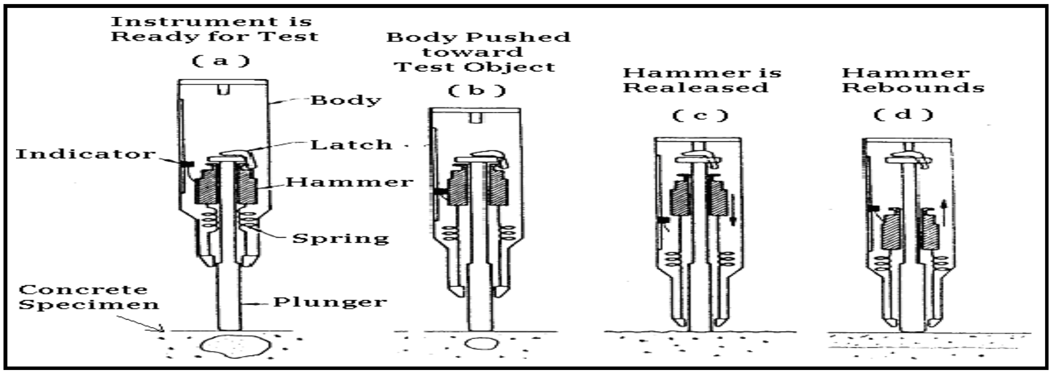


Impact Energy of Rebound Hammers

Depending upon the impact energy, the hammers are classified into four types i.e. N, L, M & P. Type N hammer having an impact energy of 2.2 N-m and is suitable for grades of concrete from M-15 to M-45. Type L hammer is suitable for lightweight concrete or small and impact sensitive part of the structure. Type M hammer is generally recommended for heavy structures and mass concrete. Type P is suitable for concrete below M15 grade.

Working of rebound hammer: A schematic cut way view of schmidt rebound hammer is shown in fig. 1. The hammer weight about 1.8 kg., is suitable for use both in a laboratory and in the field. When the plunger of rebound hammer is pressed against the surface of concrete, a spring controlled mass rebounds and the extent of such rebound depends upon the surface hardness of concrete.

The rebound distance is measured on a graduated scale and is designated as rebound number. Basically, the rebound distance depends on the value of kinetic energy in the hammer, prior to impact with the shoulder of the plunger and how much of that energy is absorbed during impact. The energy absorbed by the concrete depends on the stress-strain relationship of concrete. Thus, a low strength low stiffness concrete will absorb more energy than high strength concrete and will give a lower rebound number.



Schematic Cross Section of Rebound Hammer & Principle of Operation

Method of testing (operation)

1. To prepare the instrument for a test, release the plunger from its locked position by pushing the plunger against the concrete and slowly moving the body away from the concrete. This causes the plunger to extend from the body and the latch engages the hammer mass to the plunger rod.
2. Hold the plunger perpendicular to the concrete surface and slowly push the body towards the test object. (The surface must be smooth, clean and dry and should preferably be formed, but if trowelled surfaced are unavoidable, they should be rubbed smooth with the carborundum stone usually provided with the equipment. Loose material can be ground off, but areas which are rough from poor compaction, grout loss, spalling or tooling must be avoided, since the results will be unreliable).
3. As the body is pushed, the main spring connecting the hammer mass to the body is stretched. When the body is pushed to the limit, the latch is automatically released and the energy stored in the spring propels the hammer mass towards the plunger tip. The mass impacts the shoulder of the plunger rod and rebounds.
4. During rebound, the slide indicator travels with the hammer mass and records the rebound distance. A button on the side of the body is pushed to lock the plunger in the retracted position and the rebound number is read from the scale.

The test can be conducted horizontally, vertically upward or downward or at any intermediate angle. Due to different effects of gravity on the rebound as the test angle is changed, the rebound number will be different for the same concrete. This will require separate calibration or correction charts, given by the manufacturer of the hammer.

Correlation procedure: Each hammer is provided with correlation curves developed by the manufacturer using standard cube specimens. However, the use of these curves is not recommended because material and testing conditions may not be similar to those in effect when the calibration of the instrument was performed. A typical correlation procedure is given as below:

1. Prepare a number of 150 mm cube specimens covering the strength range to be encountered on the job site. Use the same cement and aggregates as are to be used on the job. Cure the cubes under standard moist curing room conditions.
2. After capping, place the cubes in a compression testing machine under an initial load of approximately 15% of the ultimate load to restrain the specimen. Ensure that cubes are in saturated surface dry conditions.
3. Make 5 hammer rebound readings on each of four moulded faces without testing the same spot twice and minimum 20 mm gap from edges.
4. Average the readings and call this the rebound number for the cube under test.
5. Repeat this procedure for all the cubes.
6. Test the cubes to failure in compression and plot the rebound numbers against the compressive strength on a graph.
7. Fit a curve or a line by the method of least squares.

It is important to note that some of the curves deviate considerably from the curves supplied with the hammer.

Limitations: Although the rebound hammer provides a quick inexpensive means of checking the uniformity of concrete, it has serious limitations and these must be understood clearly for interpretation of test results.

Factors affecting rebound number

The results of Schmidt rebound hammer are significantly influenced by the following factors

a. Smoothness of Test Surface
b. Size, Shape and Rigidity of the Specimen
c. Age of Test Specimen
d. Moisture Condition
e. Type of Coarse Aggregate
f. Type of Cement
g. Type of Mould
h. Surface Carbonation

Influence of these factors has different magnitudes. Hammer orientation will also influence the measured values, although correction factors can be used to allow for this effect.

Precautions to be taken while using rebound hammer: The following precautionary measures are taken while using the rebound hammer which may give rise to minimize error

- The surface on which the hammer strikes should be smooth and uniform.Moulded faces in such cases may be preferred over the Trowelled faces.
- The test hammer should not be used within about 20 mm from the edge of thespecimen.
- Rebound hammer should not be used over the same points more than once.
- The rebound test must be conducted closely placed to test points, on at least 10 to 12 locations while taking the average extremely high and low values of the index number should be neglected.

Surface Hardness of concrete based on Average Rebound Hammer

Average rebound number	Surface Hardness
> 40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
< 20	Poor

Preparation of Specimen

Cubes were cast, targeting at different mean strengths. Further, the cubeswere cured for different number of days to ensure availability of a wide range of
Compressive Strength attained by these cubes. Size of each cube was 150×150×150mm.

Testing of Specimen

1. 10 readings (rebound numbers) were obtained for each cube, at different locations on the surface of the specimen.
2. The cube was divided into grid blocks of equal spacing and 10 points were marked at equal intervals for taking the Rebound Hammer test.
3. The cubes were then given a load of 7 N/mm^2 (as specified by the IS 13311) in the Compression Testing Machine and the Rebound Values were obtained.
4. The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained.

Ultrasonic Pulse Velocity Test

Description of Test

The ultrasonic pulse velocity method is used for non-destructive testing of plain,reinforced and prestressed concrete whether it is precast or cast in-situ

Objects: The main objects of the ultrasonic pulse velocity method are to establish

- The Homogeneity of the Concrete
- The Presence of Cracks, Voids and other Imperfections

- Changes in the Structure of the Concrete Caused by the Exposure Condition,Corrosion, Wear etc. which may occur with time,
- The Quality of the Concrete in Relation to the Specified Standard Requirements.
- The Quality of One Element of Concrete in Relation to the Another.
- The Values of the Dynamic Elastic Modulus of the Concrete.

Principle: This is one of the most commonly used method in which the ultrasonic pulses generated by electro-acoustical transducer are transmitted through the concrete. In solids, the particles can oscillate along the direction of sound propagation as longitudinal waves or the oscillations can be perpendicular to the direction of sound waves as transverse waves. When the pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves is developed which includes convert electrical signals into mechanical vibrations (transmit mode) and mechanical vibration into electrical signals (receive mode). The travel time is measured with an accuracy of +/- 0.1 microseconds. Transducers with natural frequencies between 20 kHz and 200 kHz are available, but 50 kHz to 100 kHz transducers are common. The receiving transducer detects the onset of the longitudinal waves which is the fastest wave. Because the velocity of the pulses is almost independent of the geometry of the material through which they pass and depends only on its elastic property. Under certain specified conditions, the velocity and strength of concrete are directly related. The common factor is the density of concrete; a change in the density results in a change in a pulse velocity, likewise for a same mix with change in density, the strength of concrete changes. Thus lowering of the density caused by increase in water-cement ratio decreases both the compressive strength of concrete as well as the velocity of a pulse transmitted through it.

Pulse Velocity method is a convenient technique for investigating structural concrete. The underlying principle of assessing the quality of concrete is that comparative higher velocities are obtained when the quality of concrete in terms of density, homogeneity and uniformity is good. In case poorer quality of concrete, lower velocities are obtained. If there is a crack, void or flaw inside the concrete which comes in the way of transmission of the pulses, the pulse strength is attenuated and it passes around the discontinuity, thereby making path length longer. Consequently, lower velocities are obtained. The actual pulse velocity obtained depends primarily upon the material and the mix proportion of the concrete. Density and modulus of elasticity of aggregate also significantly affect the pulse velocity.

Transducers: Piezoelectric and magnetostrictive types of transducers are available in the range of 20 kHz to 150 kHz of natural frequency. Generally, high frequency transducers are preferable for short path length and low frequency transducers for long path lengths. Transducers with a frequency of 50 to 60 kHz are useful for most all- round applications.

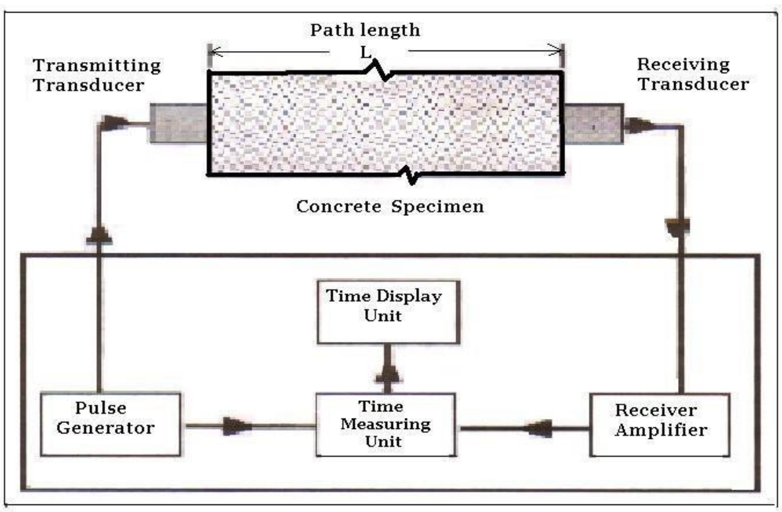


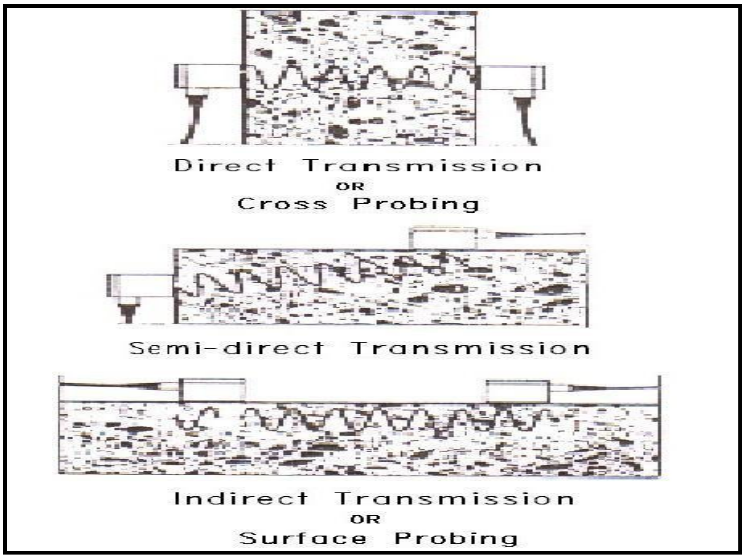
Fig. 3.5: Schematic Diagram of Ultrasonic Pulse Velocity Method

There are three possible ways of measuring pulse velocity through concrete:

Direct Transmission (Cross Probing) through Concrete: In this method transducers are held on opposite face of the concrete specimen under test as shown in fig. The method is most commonly used and is to be preferred to the other two methods because this results in maximum sensitivity and provides awell defined path length.

Semi-direct Transmission through Concrete: Sometimes one of the face of the concrete specimen under test is not accessible, in that case we have to apply semi-direct method as shown in fig. In this method, the sensitivity will be smaller than cross probing and the path length is not clearly defined.

Indirect Transmission (Surface Probing) through Concrete: This method of pulse transmission is used when only one face of concrete is accessible. Surface probing is the least satisfactory of the three methods because the pulse velocity measurements indicate the quality of concrete only near the surface and do not give information about deeper layers of concrete. The weaker concrete that may be below a strong surface can not be detected. Also in this method path length is less well defined. Surface probing in general gives lower pulse velocity than in the case of cross probing and depending on number of parameters.



Different Methods of Propagating Ultrasonic Pulses through Concrete

Velocity Criteria for Concrete Quality Grading

As per Table 2 of IS 13311 (Part 1): 1992

Sr. No.	**Pulse Velocity by Cross Probing (km/sec)**	**Concrete Quality Grading**
1.	Above 4.5	Excellent
2.	3.5 to 4.5	Good
3.	3.0 to 3.5	Medium
4.	Below 3.0	Doubtful

Note: In case of doubtful quality of concrete, it may be necessary to carry out further tests.

Combined methods: There are different non-destructive testing methods which can be broadly classified as those which measure the overall quality of the concrete, dynamic or vibration methods like resonance frequency and ultrasonic pulse velocity tests and those which involve measurement of parameters like surface hardness, rebound, penetration, pull-out strength etc. are believed to be indirectly related to the compressive strength of concrete. In addition, radiographic, radiometric, nuclear, magnetic and electrical methods are also available. Since such non-destructive tests are at best indirect methods of monitoring the particulars, characteristics of concrete. The measurements are influenced by materials, concrete mix proportions and environmental factors. When the data of the materials and mix proportions used in the construction are not available, as is often the case, In view of the limitation of the methods for the predicting the strength of concrete in the structure, IS 13311 (Part 1) : 1992 Code has suggested to use combined method of ultrasonic pulse velocity and rebound hammer methods to alleviate the errors arising out of influence of materials, concrete mix proportions and environmental parameters on the respective measurement.

The use of more than one methods are capable of providing useful information and statically improved accuracy for estimation of in situ strength of concrete.

Combination of ultrasonic pulse velocity method and Schmidt rebound hammer may result much better estimation of strength of concrete because the influence of certain factors in the composition of the concrete and its curing are minimized.

Factors Affecting the Measurements of Pulse Velocity

- Smoothness of Concrete Surface under Test
- Moisture Condition of Concrete
- Influence of Path Length on Pulse Velocity
- Lateral Dimensions.
- Temperature of Concrete
- Effect of Reinforcing BarsInfluence of stress

Preparation of Specimen

Cubes were cast, targeting at different mean strengths. Further, the cubes were cured for different number of days to ensure availability of a wide range of Compressive Strength attained by these cubes. Size of each cube was 150×150×150 mm.

Testing of Specimen

1. readings of Ultrasonic Pulse Velocity (USPV) were obtained foreach cube.
2. The cubes were then given a load of 7 N/mm^2 (as specified by the IS13311) in the Compression Testing Machine and the USPV were obtained.
3. The cubes were then loaded up to their ultimate stress and theBreaking Load was obtained.
   The tables lists the Dead Load on the specimen at the time of testing, the Breaking Load, Mean Rebound Value, Mean Pulse velocity value along with estimated Compressive Strength as obtained by the Compression Testing Machine.

Water absorption test and Porosity test

The aim of this study is to determine the total water absorption capacity and measure the volume of voids present in controlled and bacteria incorporated concretes of ordinary (M20), standard (M40) and high strength (M60 and M80) grades as per ASTM C642-13. The total quantity of water absorbed is related to the total open porosity, while the kinetics of the process depends principally on the distribution of the pore sizes. This test also measures the capillary rise of water, the most common form of liquid water migration into concrete which is inversely proportional to the diameter of the pores. Absorption is the capacity of a sample to hold water while capillary is the rate at which the water fills the sample. Concrete cube samples of size 100 x 100 x 100 mm are casted and cured for 28 days for testing. Determining the sorptivity of a sample in the lab is a simple, low technology technique, all that is required, is a scale, a stopwatch and a shallow tub of water. The samples 100 x 50 mm size cylindrical specimens are preconditioned to a certain moisture condition, either by drying the sample for 7 days in a 50°C oven. Sorptivity measures the rate of penetration of water into the pores in concrete by capillary suction. It is also a measure of the capillary forces exerted by the pore structure causing fluids to be drawn in to the body of the material. It provides a relative measure that combines pore size diameter and number of pores present.

Porosity by the gravity method

This method consists of saturating the concrete sample of size 100 x100 mm cube. Once it is fully saturated, it is weighted with centigram precision and its volume V is determined by weighing. Then, the sample is submitted to moderate oven drying at a temperature of 60 ±2 °C. The drying is stopped when the weight of the sample remains constant. The weight of the dried sample is obtained after 21 days of drying.

Porosity, p is then determined using the following formula:

M_{sat} - M_{dry}P=-------------

ρ_w V

Where ρ_w the unit mass of water (1 g/cc), V is the volume of sample (100 x 100 x100 mm^3), M_{dry} and M_{sat} denote the weight of the dried and fully saturated samples, respectively. The porosity can be expressed either as a fraction or as a percentage.

Table 3.5: Durability Classification as per ASTM C 642

Classification	Volume of Permeable Voids (VPV) (% by volume)	Water Absorption Capacity (% by weight)
Excellent	<14	<5
Good	14-16	5-6
Normal	16-17	6-7
Marginal	17-19	7-8
Bad	>19	>8

ASTM C1585 Sorptivity Test

Determining the sorptivity of a sample in the lab is a simple, low technology technique, all that is required, is a scale, a stopwatch and a shallow tub of water. The samples 100 x 50 mm size cylindrical specimens are preconditioned to a certain moisture condition, either by drying the sample for 7 days in a 50°C oven. The sides of the concrete sample are sealed, typically with electrician's tape or by sealant while the suction face and the face opposite it were left unsealed. Cylindrical concrete specimens were placed on a filtered support (sponge) so that the water level was 10±1 mm above the inflow face as shown in Fig.7.18. The sample is immersed to a depth of 5-10 mm in the water then the initial mass of the sample and time of start are recorded. The procedure of recording mass of the sample was repeated, consecutively, at various times such as 15 min, 30 min, 1 hr, 2 hr, 4 hr, 6 hr, 24 hr, 48 hr and 72 hr. The gain in mass per unit area over the density of water (I) is plotted versus the square root of the elapsed time (√t). The slope of the line of best fit of these points (ignoring the origin) is reported as the sorptivity coefficient (k). The rate of water absorption or sorptivity (k), is the slope of I- √*t* graph (m / $min^{1/2}$ or kg/ m^2 / √ min).

For one dimensional flow, it can be stated that (Hall, 1989):

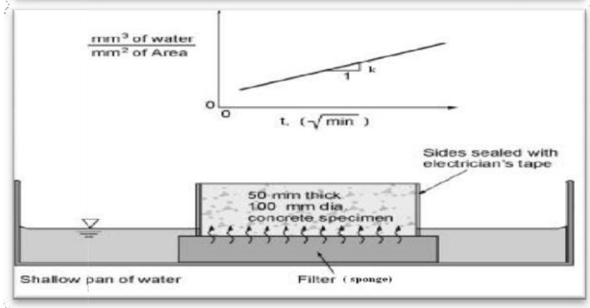
I = k x √t Where k is sorptivity coefficient and I = W/ (A x d)

W = the amount of water absorbed in kg

A= Area of the c/s of the specimen that is in contact with water (m^2)

d= density of the medium in which the specimen was dipped (1000 kg/m^3 in case medium is water)

Because of small initial surface tension and buoyancy effects, the relationship between cumulative water absorption (kg/m^2) and square root of exposure time ($t^{0.5}$) shows deviation from linearity during first few minutes. Thus, for the calculation of sorptivity coefficient, only the section of the curves for exposure period from 15 min to 72 hrs, where the curves were consistently linear, was used for the calculation of sorptivity.

Experimental Setup for Sorptivity Test

TEST RESULTS AND DISCUSSIONS OF TESTRESULTS

Mix Proportions

Grade used M20

The final mix proportions of M-20 grade of concrete become:-

Mix Proportions

Water	Cement	FA	CA
180.42	360	584	1223.8
0.50	1.00	1.62	3.40

FLY ASH.

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitatorsor filter bags. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generallyspherical in shape and range in size from 0.5 µm to 100 µm. They consist mostly of silicon dioxide (SiO_2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp,
pointed and hazardous; aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3). Fly ashes are generally highly heterogeneous, consisting of a mixture of glassy particles with various identifiable crystalline phases such asquartz, mullite, and various iron oxides. For the concrete mix so produced we use Class F flyash.

Properties of expanded polystyrene beads

Properties of Expanded Polystyrene Beads

Specific Gravity	Bulk density	Particle size
0.011	6.86 kg/m^3	Spherical (8-9 mm dia)

Densities of Different Concrete Cubes

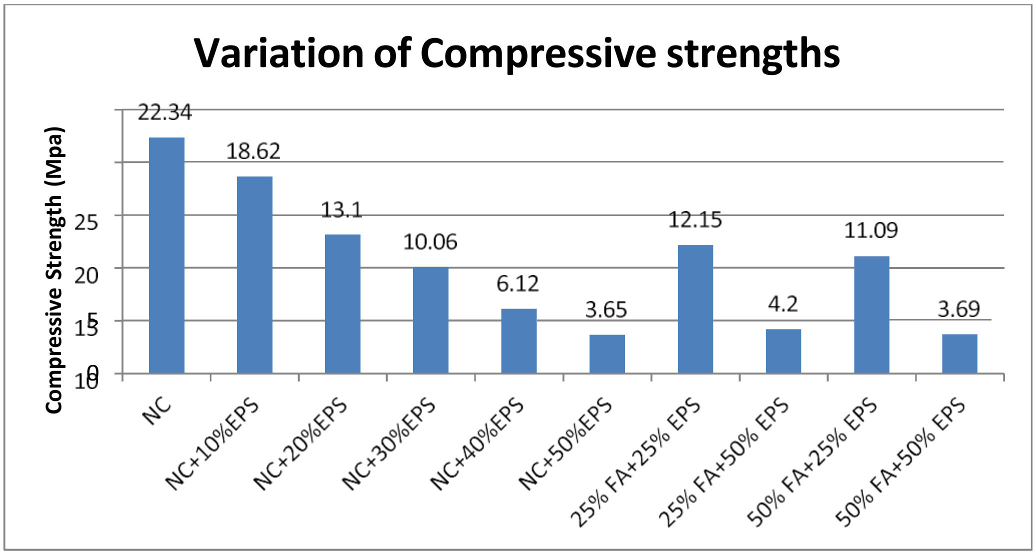
Densities of Concrete Cubes

TYPE OF CONCRETE	**FLY ASH%**	**EPS%**	**Density kg/cub. m**
NORMAL CONCRETE(M20)(NC)	0	0	2121.48
NC+10%EPS	0	10	1816.30
NC+20%EPS	0	20	1608.89
NC+30%EPS	0	30	1374.81
NC+40%EPS	0	40	1244.44
NC+50%EPS	0	50	1179.26
FLYASH CONCRETE (FAC) 25% FA+25% EPS	25	25	1416.30
FLYASH CONCRETE (FAC) 25% FA+50% EPS	25	50	1099.26
FLYASH CONCRETE (FAC) 50% FA+25% EPS	50	25	1351.11
FLYASH CONCRETE (FAC) 50% FA+50% EPS	50	50	1084.44

Compressive Strength Test Results

Compressive Strength Results

TYPE OF CONCRETE	FLY ASH%	EPS %	COMPRESSIVE STRENGTH (MPA)	% REDUCTION IN
NORMAL CONCRETE(M20)(NC)	0	0	22.34	-
NC+10%EPS	0	10	18.62	16.65
NC+20%EPS	0	20	13.10	41.36
NC+30%EPS	0	30	10.06	54.97
NC+40%EPS	0	40	6.12	72.61
NC+50%EPS	0	50	3.65	83.66
FLYASH CONCRETE (FAC) 25% FA+25% EPS	25	25	12.15	45.61
FLYASH CONCRETE (FAC) 25% FA+50% EPS	25	50	4.20	81.20
FLYASH CONCRETE (FAC) 50% FA+25% EPS	50	25	11.09	50.36
FLYASH CONCRETE (FAC) 50% FA+50% EPS	50	50	3.69	83.48



Variation of Compressive Strengths for different proportions

It is observed that, the larger the amount of polystyrene beads in concrete, the lesser the compressive strength. As expected, the normal weight concrete has more compressive strength at all ages compared to lightweight concrete.

EPS based concrete mixes, in general, decrease with an increase in polystyrene beads content. This can be attributed to,

- Increase in polystyrene volume, increases the voids as compared to the control mix.
- Smooth surface of the polystyrene; hence the polystyrene beads tend to bond loosely with the cement paste. It is seen that the polystyrene particles could be easily plucked and removed from therupture surfaces of the cubes after compression tests. Due to this poor bond characteristic, failure takes place through the cement paste- polystyrene interface at much lower stress levels.
- Low specific gravity of the polystyrene due to which there is a reduction in overall density of the concrete. Density affects the compressive strength i.e., an increase in the density of the mix will increase its compression strength.

Ultrasonic Pulse Velocity Test Results

Ultrasonic Pulse Velocity Test Results

TYPE OF CONCRETE	FLY ASH%	EPS%	Weight (kg)	USPV km/sec	Quality Of concrete
NORMAL CONCRETE(M20) (NC)	0	0	7.16	4.0	Good
NC+10%EPS	0	10	6.13	3.9	Good
NC+20%EPS	0	20	5.43	3.33	Medium
NC+30%EPS	0	30	4.64	3.06	Medium
NC+40%EPS	0	40	4.20	2.96	Doubtful
NC+50%EPS	0	50	3.98	2.77	Doubtful

FLYASH CONCRETE(FAC) 25% FA+25% EPS	25	25	4.78	3.28	Medium
FLYASH CONCRETE(FAC) 25% FA+50% EPS	25	50	3.71	2.79	Doubtful
FLYASH CONCRETE(FAC) 50% FA+25% EPS	50	25	4.56	3.44	Medium
FLYASH CONCRETE(FAC) 50% FA+50% EPS	50	50	3.66	2.51	Doubtful

CONCLUSIONS

The following conclusions were drawn from the study.

- Increase in the EPS beads content in concrete mixes reduces the compressive
- All the EPS concrete without any special bonding agent show good workability and could easily be compacted and finished.
- Workability increases with increase in EPS beads content.
- The replacement by using EPS has shown a positive application as an alternate material in building nonstructural members, and it also serves as a solution for EPS disposal.
- Obtained results suggest that expanded polystyrene concrete has scope for nonstructural applications, like wall panels, partition walls, etc

SCOPE FOR FURTHER WORK

PROBLEMS FACED WHILE CASTING

There are so many problems faced while casting the cubes which include:

- Firstly we considered mix proportion based on weight. As Styrofoam is light weight much more quantity of Styrofoam is required for casting one single cube not only that as Styrofoam occupies whole space binding property will be less which affects strength which decreases drastically.
- We also found that Styrofoam is segregating as the Styrofoam has smooth finishing binding property of mix is reducing.
- Polyconcrete is made by mixing the lightweight aggregate with cement, sand and water in a conventional mixer. Polystyrene beads occupy much of the volume between 600kg/m³ and 800kg/m³ where compressed aggregate occupies 60-80%, nearly all the remaining space being filled by the mortar. Since this mortar determines the mechanical properties of the material it generally has high cement content. The consistency of fresh Polyconcrete is not adequately measured by means of the tests generally employed for normal concrete. The differences arise from the high proportion of the very regular aggregate,

which gives a mix that is lean and not very cohesive, but offers little resistance to flow.

- Fresh Polyconcrete contains a high proportion of spherical aggregate, and is not very cohesive: it has a crumb like consistency. Various tests for consistence or workability has been applied to it, but the consistency categories often applied to normal concrete have been found to be generally inapplicable.

CARE AND TIPS DURING MIXING

- For stronger concrete, increase the sand used and decrease the Styrofoam by thesame amount.
- Add the Portland cement and sand to the water and mix well to create a soup.This should be a very wet consistency, not usual for cement because the polystyrene will soak up a large amount of the water.
- Styrofoam is extremely flammable, and releases a toxic gas called styrene when burnt. It is unknown at this time whether mixing it with cement would retard thisquality sufficiently to make a safe substance to use on the inside of home.

SCOPE FOR IMPROVEMENT

This paper has explored the characteristics of new lightweight concrete consisting ofpolystyrene, sand, cement and water.

Through this paper it has been proven that proposed the proposed mix is very reliable giving strength with a low density. The mechanical and chemical properties have, also, been discussed in order to study the behavior of polystyrene under different environments (i.e. field usage). The mix workability is very high at a very low water/cement ratio (down to 0.35). A new method for designing Polyconcrete mixes hasbeen introduced in a simple, yet practical and tangible way.

This work can be considered a new line of research for lightweight concrete as themixing method is very simple, relatively inexpensive and does not need complex machinery systems.

It is recommended that further work should be done to cover:

- Permeability
- Structural behavior
- Absorption, freeze and thaw durability
- Abrasion, and corrosion of steel reinforcements.
- Compaction techniques for full scale applications

The mentioned tests are essential to be carried out before the use of Polyconcrete instructural members.

REFERENCES

1. Bischoff P.H et al., ‘Polystyrene Aggregate Concrete Subjected to Hard Impact’,
2. Proceedings-Institution of Civil Engineers, Part 2: Research and Theory, Vol. 89, 1990, pp. 225-239.
3. Bungey J.H et al., Testing of Concrete in Structures, Chapman and Hall, UK, 1996
4. Hamdan.A., Kajian Rekabentuk Campuran Konkrit menggunakan Styropor sebagai Agregat Ringan, Universiti Teknologi Malaysia, 2000
5. Jackson N et al., Civil Engineering Materials, Macmillan, UK, 198
6. Neville A.M., Properties of Concrete, Longman, UK, 1995
7. Park S.G et al., ‘Report Study-Polystyrene Aggregate Concrete’, Building Research Association of New Zealand, 1999
8. Parton G.M et al., ‘Polystyrene Bead Concrete Properties and Mix Design’, Magazine of Concrete Research, Vol. 43, No. 3, 1982, pp. 153-161
9. Perry S.H et al., ‘Mix Details and Material Behavior of Polystyrene Aggregate Concrete’, Magazine of Concrete Research, Vol. 43, No. 154, 1991, pp. 71-76