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BEHAVIOUR OF LIGHTWEIGHT BEAM USING EPS BEADS AS PARTIAL REPLACEMENT OF AGGREGATES.

MUHAMMAD FARHAN BIN SOED

Report submitted in partial fulfilment of the requirements
for the award of degree of
B.Eng. (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources
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JUNE 2016

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This thesis is dedicated to my parents, siblings, and friends and to my supervisor, who gave me everlasting inspiration, the spirit to finish this thesis, the continuous encouragements and priceless supports toward the success of this study.

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ABSTRACT

Reinforced concrete is compulsory in nowadays building and they contain cement, aggregates, steel then mix with the water. The purpose of this mixture is sometimes different according what to be built. Fresh concrete can built into any shape and they are good in compression but weak in tension. The main objective of this study is to determine compressive strength and the cracking pattern of lightweight concrete to be used as normal beam by using polystyrene beads. The tests has been conducted to find compressive strength and the deflection of the beam. All the procedures are prepared accordingly, to assure the research objectives are applicable, and to secure proper sequence and smooth running of the entire flow, from start until end. Six samples had been prepapred, which two of them are ratio control, ratio and ratio 2 significantly. All six samples of the reinforced beam are concreted at Heavy Structure Laboratory, University Malaysia Pahang (UMP) and compressive strength test also conducted at same laboratory. The result that had been received are likely like the theory means that the ratio control will have the highest load compare the other two ratios. As conclusion, EPS can be used as extenuating agent in concrete. However, from the observation, we can hardly distinguish which of normal beam is stronger. Besides that, the development of the graph pattern for each sample is not consistent, thus explains the indifferences of the load bearing capacity.

ABSTRAK

Konkrit bertetulang adalah berguna di masa kini membina dan ianya mengandungi simen, agregat, keluli dicampurkan dengan air. Tujuan campuran ini agak berbeza mengikut apa yang akan dibina. Konkrit segar boleh dibina ke dalam apa-apa bentuk dan ini adalah baik dalam mampatan tetapi lemah dalam tegangan. Objektif utama kajian ini adalah untuk menentukan kekuatan mampatan dan corak keretakan konkrit ringan untuk digunakan sebagai rasuk biasa dengan menggunakan manik polistirena. Ujian telah dijalankan adalah untuk mencari kekuatan mampatan dan pesongan rasuk. Semua prosedur telah disediakan dengan sewajarnya, untuk memastikan objektif kajian yang berkenaan, dan untuk mendapatkan urutan yang betul dan kelancaran aliran keseluruhan, dari awal hingga akhir. Enam sampel telah disediakan, yang dua daripada mereka adalah kawalan nisbah, nisbah 1 dan nisbah 2 dengan ketara. Kesemua enam sampel rasuk bertetulang adalah dikonkrit dan dibancuh di Makmal Struktur Berat, Universiti Malaysia Pahang (UMP) dan ujian kekuatan mampatan juga dijalankan di makmal yang sama. Hasil yang telah diterima mungkin seperti teori bermakna bahawa kawalan nisbah akan mempunyai beban tertinggi membandingkan kedua-dua nisbah lain. Sementara itu, ketumpatan konkrit segar dengan dan tanpa EPS juga mempunyai perbezaan yang yang mengandungi EPS lebih cahaya daripada rasuk biasa. Kesimpulannya, EPS boleh digunakan sebagai ejen peringan dalam konkrit. Walau bagaimanapun, dari pemerhatian, kita boleh tidak membezakan yang rasuk biasa adalah lebih kuat. Selain itu, pembangunan corak graf untuk setiap sampel tidak selaras, dengan itu menerangkan perbezaan daripada keupayaan galas beban.

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LIST OF SYMBOLS

%	Percent
mm	Millimetre
mm^2	Millimetre square
m^3	Cubic metre
µm	Micro metre
g	Gram
kg	Kilogram
kg/m^3	Kilogram per cubic metre
N/mm^2	Newton per square millimetre
kN	Kilo newton
°C	Degree Celsius
°	Degree
kN/sec	Kilo newton per second
f_c	Compressive strength of concrete specimen
P	Maximum load carried by the specimen during testing
A	Area
R	Modulus of Rupture
R^2	Correlation coefficient
l	Distance between the support
b	Net width
d	Depth

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	British Standard
MS	Malaysian Standards
EPS	Expanded Polystyrene Styrofoam
i.e.	That is
e.g.	For example

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Reinforced concrete is compulsory in nowadays building and they contain cement, aggregates, steel then mix with the water. The purpose of this mixture is sometimes different according what to be built. Fresh concrete can built into any shape and they are good in compression but weak in tension. Many research has been done to overcome this type of situation and some of that by changing the ration of the concrete and type of aggregate. There are not so much difference after change the ratio and the aggregates but there is a slight increment in the positive aspect but there also some disadvantage on changing these two type items.

Aggregates play a huge part in mixing the concrete because the surface in the aggregates that makes the bond between the cement plus the water who bond them together to make strong hardened concrete. Common failure in aggregates are the surface which are sometimes not suitable in some part at construction because the angular shape may not be bond with the other materials. Concrete is more workable when smooth and rounded aggregate is used instead of rough angular or elongated aggregate. Most natural sands and gravel from riverbeds or seashores are smooth and rounded and are excellent aggregates. Crushed stone produces much more angular and elongated aggregates, which have a higher surface-to-volume ratio, better bond characteristics but require more cement paste to produce a workable mixture.

There also moisture in aggregates but there are small amount of it and the density of the aggregates makes it heavier. Nowadays there are many research on lightweight concrete which aggregates play a huge part in it for example oil coconut shell, seashell and many others. So what my research is about changing the normal coarse aggregates with what we are normally called polystyrene and also called expanded polystyrene beads. The characteristics of the polystyrene may affect some of the criteria on the concrete. This EPS which are lighter in weight are one of the advantage of using it plus the smooth surface of it. If the surface is smooth, the bonding between other materials may be strong and bond tightly together. These can make the concrete gain more strength to support the load.

With these changes can it make the structure stronger and durable to the construction because there so many aspect that can affect the structure nowadays for example from the natural disaster, can the structure withstand the load or pressure given to the structure plus can it long lasting.

1.2 PROBLEM STATEMENT

Reinforced concrete is usually used as a structure part in construction. But there are some weakness in each of the item used that may cause defect on the construction. For each item that use in concrete structure there must be weakness in one each of them. During the life service these structures are subjected to many loads, wind gravity and else. These can make the life of the structure become shorten or not strong enough. What we can do is try to minimize the risk by changing certain aspect to make the structure stronger and also long lasting.

Plus nowadays the cost is expensive because usually in structure of the concrete there will need many items for mixture and in this case is aggregates which are more expensive day by day. And the quality of the aggregates may not be suitable with price give and to fit in some construction project. Because as we all know aggregates are not all the same because of their shape especially, the density of the aggregates. And the technology nowadays are more to greener which to save the environment, so that we can save some cost by changing the normal aggregate with polystyrene , there may not be all to change to polystyrene but maybe we can change some of the aggregates with expanded polystyrene beads.

As we all know the normal aggregates is much heavier than the polystyrene because they contain more moisture content. Compare to the EPS they are light in weight plus their surface are usually similar to each other and their surface is very smooth compare to the normal aggregates which may be rough and not same in shape. If we using the EPS as partial replacement of the aggregates it can make the structure more light in weight and also save the cost of course.

1.3 OBJECTIVES OF THE STUDY

There are two (2) main objectives for this project:-

i. To check the deflection and type of cracking on this structure using expanded polystyrene beads (EPS) after load is applied on lightweight beam.
ii. To check and compare the capacity of normal concrete beam and lightweight beam due to optimum moment

1.4 SCOPE OF STUDY

This study is focused on the behaviour of lightweight concrete when it containing different percentage or ratios of EPS beads as partial of aggregates. The ratio are varies, for the control 1:3:0, ratio 1 1:2.5:0.5 and ratio 2 1:2:1. Two mixes batch were prepared during this study.

The size of the beam is fixed to 0.15m base x 0.3m height x 2m span dimension and for the cubes test, mould with size of 100mm x 100mm x 100mm is used. For the curing process, the period of the concrete cube subjected to water is 7 and 28 days. The methods used for curing is water curing. The test for compressive and flexural strength of the concrete cube is conducted after the process of curing for each specimen.

1.5 IMPORTANCE OF STUDY

This study will provide all the information and knowledge regarding EPS beads as the partial replacement of aggregates in concrete. The strength, durability and the effect of the composition will be identified later on this study. The result from this study is expected to help reducing the heavy of weight of normal reinforced beam. Furthermore, the information gained from this study will provide better understanding about this modified concrete mixture for further study.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

2.1.1 PROPERTIES REINFORCED POLYSTYRENE CONCRETE BEAM

Expanded polystyrene is an extremely lightweight materials and extensive investigation into the properties of polystyrene-aggregate concrete (PAC) or also called EPS has been conducted in many research. The polystyrene are very light so it easily can be handle but it can withstand small load on it. Next it can reduce the size of foundation and it has low thermal conductivity which so suitable if there is an earthquake because of its absorption properties. (AdComp96)

Table 2.1 Fresh and Hardened Properties of Concrete Mixtures

Properties	Normal Weight Concrete	Polystyrene aggregate concrete
Slump (mm)	85	140
Compacting factor	0.94	0.98
Vebe time (sec)	4.0	3.5
Unit weight (kg/ m^3)	2405	2160
28-day cylinder strength (MPa)	34.6	31.1
28-day Static Modulus Elasticity (GPa)	30.1	26.6

Source: (K L Lai,B. Hall 2007)

As we can see the polystyrene are 10% lighter than normal weight concrete and it has better workability based on the table above. Experience with polystyrene aggregate concrete (PAC) indicated that care must be exercised while mixing, pouring and compacting of fresh concrete to minimise segregation of the concrete mixture. It was noticed that fairly a uniform concrete may be achieved by limiting the amount of vibration to a period when polystyrene beads just start to accumulate at the top of the concrete member. But in order to achieve a good compaction at the same time, it was found necessary to add super plasticizer to the concrete mix to improve its workability.

Experience with polystyrene aggregate concrete indicated that care must be exercised while mixing, pouring and compacting of fresh concrete to minimise segregation of the concrete mixture. It was noticed that fairly a uniform concrete may be achieved by limiting the amount of vibration to a period when polystyrene beads just start to accumulate at the top of the concrete member. But in order to achieve a good compaction at the same time, it was found necessary to add super plasticizer to the concrete mix to improve its workability. The addition of polystyrene beads reduced the workability of the concrete probably due to the water absorption by the patented coating to the polystyrene aggregate particles. (Anniamma Chacko, 2013)

The unit weight of polystyrene aggregate concrete was 2160 kg/m3 compared to 2405 kg/m3 for the normal weight concrete. Therefore, PAC is about 10% lighter than the normal weight concrete. The workability of PAC is better than that for the normal weight concrete due to the use of superplasticizer. The 28-day compressive strength and static modulus of PAC were 31.1 MPa and 26.6 GPa respectively compared to 34.6 MPa and 30.1 GPa for the normal weight concrete.

In addition styrofoam filled with 30% in the tension area and truss system reinforcement (BSCTR), bending strength increased. It is the result of a combination of 30% Styrofoam concrete cracks that slow start and confine of the truss system reinforcement cumulatively increasing the bending strength. Monitoring of the crack propagation in each of the test material. Looks can be observed on the beam control that cracks began to spread when the load is at the level of about 8 kN. Cracks continue to spread until they reached ultimate load beam. Based on the pattern of cracks and crack propagation phenomena, it can be concluded that the beam is Styrofoam-filled give advantages and well conditions, the length of crack propagation patterns are not straight up, compared to the normal beam (BN) and externally reinforced beams.

All specimens showed flexural collapse. But on BTR test materials with truss reinforcement shows reduction deflection, but after the compression area cracked concrete directly experiencing failure. In the normal beam (BN) damage also occurred to the upper part of the concrete. The tensile strength Styrofoam-filled concrete has better tensile strength than normal concrete. (Suresh G.S, 2012)

Relationships load and deflection in the beams with SFC-30 using truss system reinforcement exhibits better ductility displacement than normal concrete beams. Flexural capacity of composite concrete beams with SFC-30 using truss system reinforcement, have increase ultimate load to 48.3 kN, and the addition of expanded material on tension polystyrene styrocon area has resulted in higher elongation than normal concrete. In the beams with SFC-30 using truss system reinforcement, crack propagation is taking place more slowly and smaller than the length cracks in normally reinforced concrete beams and externally reinforced concrete beam where crack propagation patterns are not straight up

2.1.2 PROPERTIES OF REINFORCED CONCRETE

The most valuable feature of concrete is its high compressive strength, which finds wide application in concrete and reinforced concrete structures. Compressive strength is the principal parameter determining grades and classes of concretes. Fracture toughness (or crack growth resistance) is the characteristic of material determining its resistance against breakage by crack propagation. The fracture toughness characteristic is especially important for concretes since they are brittle materials and cracking is an intrinsic phenomenon for them. Many reinforced concrete structures, therefore, work in the presence of cracks

Ductility is a desirable structural property because it allows stress redistribution and provides warning of impending failure. Steel-reinforced concrete beams are under-reinforced by design, so that failure is initiated by yielding of the steel reinforcement, followed, after considerable deformation at no substantial loss of load carrying capacity, by concrete crushing and ultimate failure. This mode of failure is ductile and is guaranteed by designing the tensile reinforcement ratio to be substantially below (ACI 318 requires at least 25 % below) the balanced ratio, which is the ratio at which steel yielding and concrete crushing occur simultaneously. The reinforcement ratio thus provides a metric for ductility, and the ductility corresponding to the maximum allowable steel reinforcement ratio provides a measure of the minimum acceptable ductility.

Concretes as structural materials are distinguishable by their high microstructure heterogeneity. Therefore, certain simplifications or approximations are required in the development of physical and mechanical models for stress state analysis and prediction of the strength and deformability of concretes. In particular, such models treat the concrete as elastic homogeneous continuum with some averaged Young modulus (E), Poisson ratio (v), specific fracture energy (γ) (that is, energy spent in the formation of the fracture surface unit), ultimate tensile (or bending) strength (Rbt), and ultimate compression strength (Rb). (Suresh G.S, 2012)

Concretes usually demonstrate nonlinear stress-strain dependence at both tension and compression. A generalized stress-strain curve for concrete is linear at small strains and passes extremes at larger strains in areas of both tension and compression. Concrete is an inhomogeneous material, a conglomerate of cement stone and aggregates of various sizes and hardness. The compressive or tensile strength is one of the most important physical and mechanical characteristics of concretes.

The slender RC beams behaved in expected fashion under flexural loading. As loads increased, flexural cracks increased in number, width and depth. Shear cracks and flexural-shear cracks also appeared, propagating diagonally from the loads to the supports. The widest cracks, and oftentimes the ones that proved critical, started as flexural cracks opposite the loads, then propagated vertically over the entire depth of the beam due to a combination of flexure and vertical shear. There was considerable vertical shearing displacement at these cracks, causing the laminate to start debonding where it intersected the cracks

Under-reinforced concrete beams were tested to failure under flexural loading. Table 3 shows the experimental and predicted values for the ultimate moments for the reinforced concrete beams with normal weight concrete and polystyrene aggregate concrete. The ultimate moment for the beams was predicted using the rectangular stress block analysis in AS3600 (7). The results showed that the AS3600 can be employed to yield a conservative estimate of the ultimate moment capacity of under-reinforced polystyrene concrete beams.

It was observed that there was no longitudinal slipping in of the tensile reinforcements at both ends of the polystyrene aggregate concrete beam during the entire stage of loading, indicating the existence of adequate concrete-steel bond as shown in Figure 2.1 and Figure 2.2 (K L Lai,B. Hall 2007)

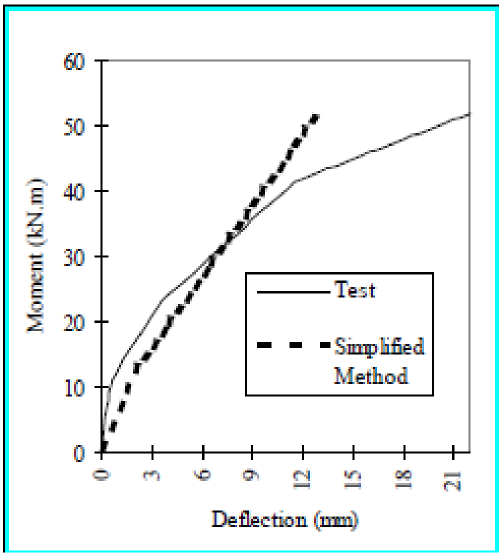

Figure 2.1

Moment-Deflection Relationship for Normal Weight Concrete RC Beam

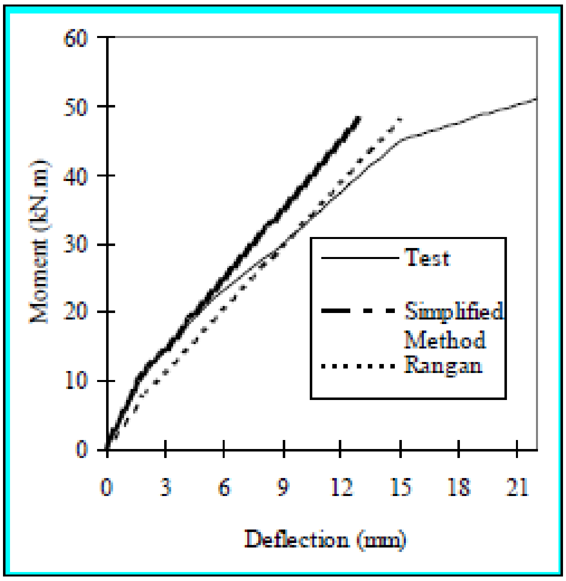

Figure 2.2

Moment-Deflection Relationship for Polystyrene Concrete RC Beam

2.1.3 APPLICATION LIGHTWEIGHT CONCRETE

Structural lightweight aggregate concrete is an important and versatile material in modern construction. It has many and varied applications including multi-storey building frames and floors, bridges, offshore oil platforms, and pre stressed or precast elements of all types. Many architects, engineers, and contractors recognize the inherent economies and advantages offered by this material, as evidenced by the many impressive lightweight concrete structures found today throughout the world. There are many types of aggregates available that are classed as lightweight, and their properties cover wide ranges. Elastic properties, compressive and tensile strength, time dependent properties, durability, fire resistance, and other properties of structural lightweight aggregate concrete are dependent on the type of lightweight aggregate utilized in the concrete.

The basic design for lightweight concrete is covered in Eurocode 2 Part 1-1, with section 11 having particular rules required for lightweight aggregate concretes. Concrete is considered to be lightweight is the density is not more than 2200kg/m^3 (the density of normal weight concrete is assumed to be between 2300kg/m^3 and 2400kg/m^3) and a proportion of the aggregate should have a density of less than 2000kg/m^3. Lightweight concrete can be specified using the notation LC for the strength class, e.g LC30/33, which denotes a lightweight concrete with a cylinder strength of 30MPa and a cube strength of 33MPa.

The lighter the concrete, the greater are the differences to be accounted for in the properties of the concrete. The tensile strength, ultimate strains and shear strengths are all lower than a normal weight concrete with the same cylinder strength. Lightweight concretes are also less stiff than the equivalent normal strength concrete. However, this is mitigated by the reduction in self-weight to be carried, so the overall effect tends to be a slight reduction in the depth of a beam or slab. (Suresh G.S, 2012)

The most significant property is reduced weight at no sacrifice in strength. Structural lightweight concrete available today are rotary kiln expanded shale, clay or slate (roughly 80% of structural use) and sintered expanded shale or clay (20%) provides the same compressive strength as normal weight aggregates with approximately the same cement content.

Other properties of lightweight concrete that may be of interest in composite design are the creep and shrinkage characteristics**.** Many engineers feel that lightweight concrete has much higher creep and shrinkage. Actually, a very extensive study of these properties shows creep to be comparable to most normal weight concrete and, on an average, shrinkage to be only moderately greater

Structural lightweight aggregate concrete solves weight and durability problems in buildings and exposed structures. Lightweight concrete has strengths comparable to normal weight concrete, yet is typically 25% to 35% lighter.
Structural lightweight concrete offers design flexibility and substantial cost savings by providing: less dead load, improved seismic structural response, longer spans, better fire ratings, and thinner sections, decreased story height, smaller size structural members, less reinforcing steel, and lower foundation costs. Lightweight concrete precast elements offer reduced transportation and placement costs

High strength concrete relies more heavily on the quality of the aggregate than does low or even medium strength concrete. The function of the aggregate, to a large extent, is to act as an inexpensive filler material. The cement paste matrix takes up most of the load imposed on the concrete. As design loads approach and exceed the strength limits of the cement paste matrix, the load carrying capacity of the aggregate and the interplay between aggregate and cement paste become the limiting factors in strength development. Mechanical characteristics of the lightweight aggregate are more similar to those of the cement paste matrix than to the normal weight aggregate, and variations in aggregate quality will be more directly reflected in the concrete characteristics.

There are many types of aggregates available that are classed as lightweight, and their properties cover wide ranges. Elastic properties, compressive and tensile strength, time dependent properties, durability, fire resistance, and other properties of structural lightweight aggregate concrete are dependent on the type of lightweight aggregate utilized in the concrete

These lightweight aggregates are relatively “light “in weight (density) due to the cellular structure of the individual aggregate particles. This cellular structure within the particles is formed at high temperatures, generally 2,000° F
(1,100° C) or higher, by the rotary kiln process. Structural lightweight aggregate concrete is defined as concrete which is made with lightweight aggregates conforming to ASTM C 330, has a compressive strength in excess of 2,500 psi (17.25 MPa) at 28 days of age when tested in accordance with methods stated in ASTM C 330, and has an air dry density not exceeding 115 pcf (1,840 kg/m3) as determined by ASTM C 567.

The use of lightweight aggregate to reduce concrete densities is a well-established procedure where properties such as increased fire resistance, ease of handling and transportation, or reduced structure dead load is desired. Lightweight concrete with compressive strengths of up to 5,000 psi (34.5 MPa) has been used in commercial construction routinely since the early 1930’s. During the last two decades, however, much higher strengths have been specified.

2.2 MATERIAL

2.2.1 EXPANDED POLYSTYRENE/ STYROFOAM

Polystyrene (STATE STANDARD R 51263-99) is a composite material consisting of Portland cement and its varieties, silica aggregate (silica sand or fly ash from thermal power station), a porous filler (foamed polystyrene granules)and modifying agents (setting accelerators, plasticizers, etc.)When we control the ratio of the components in the mixture we can get different brands of polystyrene on the indices of the average density in the dry state from D150 to D600. As a result we get both constructional and insulation material.

Aggregates normally constitute 60–70% of a concrete mix, and the physical characteristics of the aggregate will, therefore, have a pronounced influence on the physical property of the concrete. High strength concrete relies more heavily on the quality of the aggregate than does low or even medium strength concrete. The function of the aggregate, to a large extent, is to act as an inexpensive filler material. The cement paste matrix takes up most of the load imposed on the concrete. As design loads approach and exceed the strength limits of the cement paste matrix, the load carrying capacity of the aggregate and the interplay between aggregate and cement paste become the limiting factors in strength development. (Yasser, Herman Parung, 2015)

Concrete is still one of the most widely used materials in the world and estimated that its annual global production is more than 2 billion meters cubic “unpublished”. It is formed from a hardened mixture of cement, water, fine aggregate and coarse aggregate. As the main constituent of concrete materials, it is natural materials that decrease in number so that the study of natural materials that are used in the building structures optimum design is necessary to improve. (Matthew J. Heiser, 1998)

Of the various theories related to the analysis of structural elements concrete beams, it is noted that the part that its power is maximally worked in withstand bending style is the outer part only. Rose in the concrete which is compressed, while the tensile concrete which experiences strength is negligible. Therefore it is not efficient when the unoptimally working concrete core parts is made from the same type of optimally working concrete. (K L Lai, R Sri Ravindrarajah, W Pasalich, and B. Hall *2007)*

EPS thermal insulation products are lightweight and have stable, long-term thermal resistance. They are cost-effective when compared to other rigid board insulations on the basis of R-value. EPS is considered water resistant and vapour permeable. It's an inert, non-biodegradable organic plastic foam that will not rot and is highly resistant to mildew. EPS is classified as environment friendly because it does not depend on natural resources and is totally recyclable. No skilled labour is required to erect a house from these panels and they can be transported with a bakkie and trailer. They are versatile, compatible and light weight.

"These systems are highly adaptable, any architectural design or engineering application is possible. The only limitation is the imagination of the architect. The panels allow for fast and easy construction. Using insulating concrete forms results in a faster and more efficient building cycle," adds Mynhardt. "We found that the EPS used in our system provides extremely good acoustical properties as well, which makes it a sound choice for high density housing such as townhouses. We've used the system to build houses, boundary walls, suspension floors and roofs, pillars, and swimming pools."

Styrofoam or expanded polystyrene is known as white foam which is usually used for packaging electronic items and often becomes garbage dumping. Polystyrene is produced from styrene (C6H5CH9CH2) that cannot be decomposed by soil thus reduced the quality of land fertility, when it is burned, it produces carbon oxides (COX), which lead to global warming as well as the combustion becomes a liquid plastic leading to soil and water pollution. Thus the use of lightweight concrete styrocon in the core layer or under normal-light layered beam not only reduce the weight of construction but also has environmental aspects.

Figure 2.3 Expanded Polystyrene Styrofoam

The use of Styrofoam material in concrete by utilizing waste concrete can reduce construction costs, slow the onset of the heat of hydration, low the density of concrete, and reduce the earthquakes load which is smaller the works due to heavy reduced concrete structures. That in the end the exploitation of natural materials such as sand, gravel, and cement for building materials can be reduced. However, the using of low compression strength material such as SFC on tension zone of a beam may affect to the mechanical action between compression and tension. The optimization improves the structural performance of each panel in the multiple loading cases and minimizes the structural weight simultaneously. However, the using of low compression strength material such as SFC on tension zone of a beam may affect to the mechanical action between compression and tension. In this case, the application of frame system may a good alternative

Table 2.2 Characteristic of Concrete and Reinforced Steel

(Yasser, Herman Parung, 2015)

Concrete Parametric	Normal	Styrocon	Steel Parametric	Value
Force of compression	25.8 MPa	12.2 MPa	f_y	426 MPa
Force of tension	3.74 MPa	1.38 MPa	f_{smax}	594 MPa
Force of flexural	3.96 MPa	3.32 MPa	ε_s	0,0018
Modulus of elasticity	23.38 GPa	14.34 GPa	E_s	200 GPa

Low absorption lightweight aggregates are most desirable for developing a concrete mixture of high strength and durability. It is noted that values of creep and shrinkage strain for these lightweight concretes were low compared to national averages. He also noted that values of the elastic modulus were significantly higher than predicted.

Foamed polystyrene pellets contain up to 10-15% of moisture, besides there is a negative pressure inside the pellets due to condensation of water steam. This may lead to deformation (compression) of foamed polystyrene pellets. Pellet compression dramatically reduces the amount of material and leads to a significant increase in bulk density. That's why foamed polystyrene granules must be dried to stabilize the internal pressure and hardening of the outer walls of the granules. The use of pneumatic drying and transporting units for foamed polystyrene allows us to quickly and effectively reduce the residual moisture content of the material to 6.3%, while moving the material into maturing bins. Foamed polystyrene pellets remain in the maturing bin about 4-12 hours, depending on the grain size, bulk density and residual moisture. Significant reduction in the exposure time can be achieved by applying the method of pumping granules with heated air flow from on bin to another. In this case maturing time is reduced to 2-3 hours.

The speed of hardening of the polystyrene mass in the moulds depends on the following major factors: binder activity, temperature in the room and the presence of thermal processing chamber. Using the chamber allows you to speed up the process of getting demoulding strength, as well as to obtain polystyrene concrete with high strength characteristics. Use of mobile forms with demountable sides allows you to eliminate lifting mechanisms from the process, which in turn reduces the consumption of materials and material costs. (K L Lai,B. Hall *2007)*

Polystyrene concrete combines high-quality technical, operational and cost characteristics and is the best alternative to the traditional heat and sound-insulating materials. Many of Russia's architects, builders and the tenants have appreciated the outstanding properties of polystyrene concrete as the most appropriate modern and promising material for efficient construction. (Yasser, Herman Parung, 2015)

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. Expanded polystyrene (EPS) concrete is a lightweight, low strength material with good energy-absorbing characteristics. However, because of the light weight of EPS beads and their hydrophobic surface, EPS concrete is prone to segregation during casting, which results in poor workability and lower strength

2.2.2 ORDINARY PORTLAND CEMENT

Cement is a material having adhesive and cohesive properties enabling it to form good bond with other materials. In concrete, cement is the main constituent which is the only active binding media and the only component scientifically controlled. Cement has got the property of setting and hardening by virtue of chemical reactions with water at normal temperature. Factory fresh cement will reach the consumer only after some days. The cement thus received at the consumer’s end will be consumed after some days or even after some months. Cement stored at various storage conditions and exposed to varying climatic conditions definitely might have undergone some changes in its properties. When Portland cement is mixed with water to make paste, it becomes gradually less plastic and finally becomes a hard mass. When it loses plasticity, it is sufficiently rigid to withstand a definite amount of pressure. Setting is the term used to describe the stiffening of cement paste. The setting time is divided into two parts, initial setting time and final setting time. The time at which the cement paste loses its plasticity after the addition of water is known as initial setting time. The time corresponding to the paste becoming a hard mass is known as final setting time. It is essential that the initial setting time should not be too less to allow time for mixing, transporting and placing of concrete. (Jan Gijsbers, 2000)

The ASTM Spec. C150 provides for eight types of Portland cement: Types I, IA, II, IIA, III, IIIA, IV, and V, where the “A” denotes an air-entraining cement. These cements are designed to meet the varying needs of the construction industry. Cements used in wells are subjected to conditions not encountered in construction, such as wide ranges in temperature and pressure. For these reasons, different specifications were designed and are covered by API specifications. API currently provides specifications covering eight classes of oil well cements, designated Classes A through H. API Classes G and H are the most widely used.

The basic raw materials used to manufacture Portland cements are limestone (calcium carbonate) and clay or shale. Iron and alumina are frequently added if they are not already present in sufficient quantity in the clay or shale. These materials are blended together, either wet or dry, and fed into a rotary kiln, which fuses the limestone slurry at temperatures ranging from 2,600 to 3,000°F into a material called cement clinker. After it cools, the clinker is pulverized and blended with a small amount of gypsum to control the setting time of the finished cement.

Fineness, or particle size of Portland cement affect rate of hydration, which is responsible for the rate of strength gain. The smaller the particle size the greater the surface area-to-volume ratio, which means more area available for water-cement reaction per unit volume. Approximately 95% of cement particles are smaller than 45 micron with the average particle size about 15 micron. Fineness is measures in terms of surface area per unit mass. (Anniamma Chacko 2013)

Soundness refers to the ability of a hardened cement paste to retain its volume after setting. Lack of soundness is observed in the cement samples containing excessive amounts of hard burnt free lime or magnesia. Consistency of a cement paste refers to its ability to flow. Normal consistency paste are required to be prepared for testing cement specimens. Initial setting time is the time that elapsed from the instance of adding water until the pastes ceases to behave as fluid or plastic. Whereas final setting time referred to the time required for the cement plaster to reach certain state of hardness to sustain some load.

The heat generated during the reaction of cement and water is known as heat of hydration. The factors affecting heat of hydration are C3A, C2S, water cement ration, fineness of cement and curing temperature. When Portland cement is mixed with water, it undergoes a chemical reaction which leads to the hardening of the material. This process is called hydration and the results are the hydration products. The hydration process can be quantified by two characteristics, the rate of reaction, and the heat of reaction. The chemical reaction continues in the presence of free water, moisture or humidity present within the mass or outside. The mix becomes harden and stronger with age. This strength development is significant in the first month but it does not continue at a much slower rate for many years

Compressive strength of hardened cement is the most important of all the properties for structural use. Hence strength tests are prescribed by all specifications for cement. Cement should be tested for its strength in the laboratory before it is used or all major projects. The strength of mortar or concrete depends on the cohesion of the cement paste, on its adhesion to the aggregate particles and to a certain extent, on the strength of the aggregate itself.

It must be understood that cement is a chemical and reacts when mixed with water. Cement particles develop a type of growth on its surface until it link up with the growth from the neighbouring cement particles. It is this linking which results in progressive stiffening, hardening and strength development. It is important to procure OPC of a reliable brand are very constant in their quality or in other words they market consistently good quality OPC which is more reliable in its performance and large variations in the properties can easily be ruled out

It is important for the consumer to know the date of packing of the OPC. Fresher the cement, better is the performance. Cement being a hygroscopic substance, can lose strength if not stored properly or if stored for long periods of time. For concrete mix designing it is a must to know the strength of OPC and its variations from time to time. Often attempts are made to do mix designs without knowing the correct grade of OPC. This leads to either unsafe or over safe mix designs. An economical and technically viable concrete mix design can be achieved only if correct strength is known. For proper quality assurance and quality control of concrete works it is a must. (Matthew J. Heiser, 1998)

For the strength requirement of concrete, W/C is usually selected depending on the quality of OPC. Excessive W/C is undesirable for both durability and strength of mortar /concrete while it is desirable for good workability of mortar / concrete, Strength of concrete is affected more by W/C than by any other factor. It durability of structures is desired, W/C should be maximum 0.5 .However with proper mix design is possible to get at site a workable mix which will have the required strength and good durability.

Capillary pores in concrete can be as large as 5mm in diameter. Number and size of pores depend on W/C used and the extent of chemical hydration that has taken place. Voids larger than capillary pores are generally due to entrapped air. Air entrapment occur due to several reasons. These voids can cause serious durability problems. Five percent voids can cause thirty percent loss of strength.

The setting time of concrete paste is defined by initial and final sets. The time at which initial set takes place is when the cement paste begin to stiffen considerably. In concrete, initial set is said to have occurred when it has reached a degree of stiffness beyond which it cannot be compacted using vibration means. The final set roughly indicate the time at which the bonding paste has started to harden just enough to support some load. . (Anniamma Chacko 2013)

2.2.3 STEEL

There are so many type of steel that we use in construction nowadays. For example there is high-yield steel, mild steel and many more. There also for high strength steel and mild steel which is cheaper. High strength steels are mainly used for structural applications and are hence also called structural steels. They can be produced with or without addition of small amount of micro alloying elements. High strength low alloy steels, commonly referred to as HSLA steels, are produced using micro alloying elements. Steels are produced using regular low-carbon compositions strengthened with manganese (Mn). Steels are then cast into slabs and hot rolled.

Reinforcing bar, or rebar, is a common steel bar that is hot rolled and is used widely in the construction industry, especially for concrete reinforcement. Steel rebar is most commonly used as a tensioning devise to reinforce concrete and other masonry structures to help hold the concrete in a compressed state. Concrete is a material that is very strong in compression, but virtually without strength in tension. To compensate for this imbalance in a concrete slabs behaviour, reinforcement bar is cast into it to carry the tensile loads. Common steel or concrete reinforcement bar is supplied with heavy ridges to assist in binding the reinforcement to the concrete mechanically this is commonly referred to as deformed bar.

Typical stress–strain curves for standard steel bars used in reinforced concrete construction when loaded monotonically in tension are shown. The curves exhibit an initial elastic portion, a yield plateau, a strain hardening range in which stress again increases with strain and finally, a range in which the stress drops off before fracture occurs. The length of the yield plateau is generally a function of the strength of the steel. Highstrength, high-carbon types of steel generally have a much shorter yield plateau than lower strength lowcarbon steel. Similarly, the cold-working of steel can cause the shortening of the yield plateau to the extent that strain hardening commences immediately after the onset of yielding. High-strength steels also have a smaller elongation before fracture than low-strength steels.

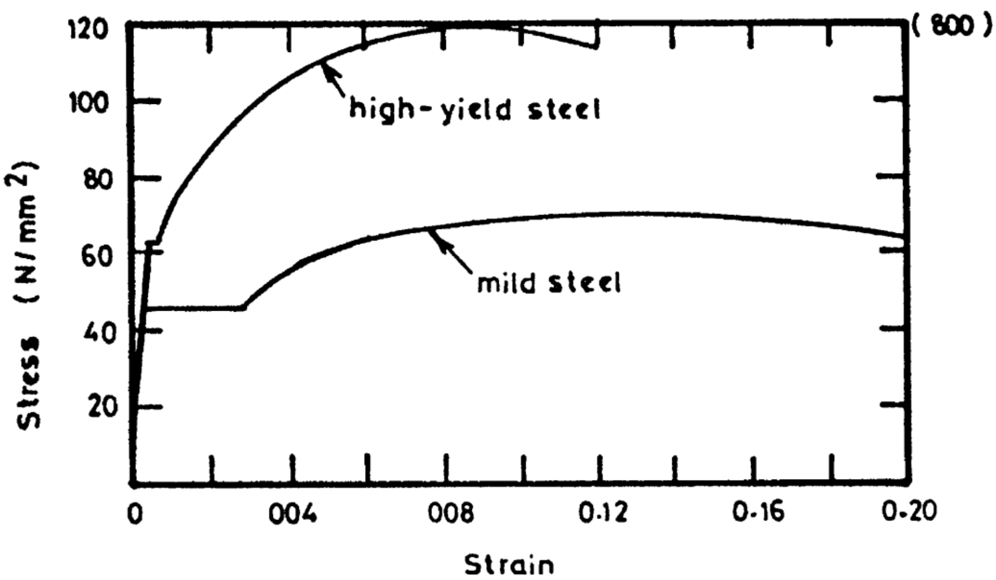

Figure 2.4 Theoretical Stress Strain graph

Source: (Jan Gijsbers, 2000)

Although the behaviour of steel is greatly affected by its chemical composition, heat treatment and the method of manufacturing, there are some physical properties that determine the behaviour of reinforcement for concrete such as yield strength, ultimate strength, Young’s modulus of elasticity, Poisson’s ratio and percentage elongation.

The minimum strain in the steel at fracture is also defined in steel specifications, since it is essential for the safety of the structure that the steel be ductile enough to undergo large deformations before fracture.

The various elements have varying effects on the behaviour of mild steel. The carbon level affects the strength and hardening properties of steel. Higher carbon contents increase strength but reduce ductility while manganese controls machinability. Excessive levels of phosphorus and sulphur, which are non-metallic impurities lead to brittle fracture and cracking problems in welded joints. For modern steel-making practice, sulphur and phosphorus are preferably maintained at less than 0.01%. Steel grades with a high level of dissolved gases, particularly oxygen and nitrogen, if not controlled by addition of small elements with a particular affinity for them to float out in the liquid steel at high temperature, can behave in a brittle manner. Manganese, chromium, molybdenum, nickel and copper also affect the strength to a lesser extent than carbon, although their sole effect is on the microstructure of the steel. . (Anniamma Chacko 2013)

The stress–strain behaviour of these steel grades has a very short range of plasticity and strain hardening at constant stress. This is normally typical of high yield carbon steel for which the spread between the yield stress and ultimate stress is relatively small. Lastly, the percentage elongation of all the samples tested was less than the minimum requirement of 22% for mild steel, and the steel bars should therefore be classified as brittle. Even though the concrete beams were designed as under-reinforced, expecting the steel which is classified as mild to yield first before the concrete started to crush with an anticipated large and plastic regime in the load–deflection curve, failure of the beams was largely brittle with very little increased deflection prior to collapse. (Jan Gijsbers, 2000)

The problem of control on reinforcing steel becomes an important issue when one considers seismic loading. In seismic design both structural and non-structural damage could occur, but collapse of the whole structure should exhibit ductility during an earthquake. It is important to ensure that in the extreme event of a structure being loaded to failure, it will behave in a ductile manner with large deformations at near maximum load-carrying capacity. The large deflections at near maximum load give ample warning of failure, and by maintaining load carrying capacity, total collapse may be prevented. . (K L Lai, B. Hall 2007)

It is necessary to have safe, economical, and easily applicable design methods for steel members subjected to fire. However, without fire protection, steel structures may suffer serious damage or even collapse in a fire catastrophe. This is because the mechanical properties of steel deteriorate by heat during fires, and the yield strength of conventional steel at 600°C is less than 1/3 of the specified yield strength at room temperature. Therefore, conventional steels normally require fire-resistant coating to be applied

Especially, temperature increase of steel and concrete in composite steel-concrete elements leads to a decrease of mechanical properties such as yield stress, Young's modulus, and ultimate compressive strength of concrete. Thus, load bearing of steel decreases when steel or composite structure is subjected to a fire action. If the duration and the intensity of the fire are large enough, the load bearing resistance can fall to the level of the applied load resulting in the collapse of the structure.

The criterion of special interest in the light of this discussion is the fact that failure of members at ultimate load should occur by tensile yielding of reinforcing steel followed by compression failure in the concrete. The type of reinforcement to use and hence, percentage of steel, therefore becomes a priority (Dat Duthinh, 2001)

There is also disadvantages of using steel which corrode due to the air moisture around. It can affect the properties of steel to binding when doing the concreting process. What we can do is try to clean the steel first, place it at the right place or we can buy stainless tell which is not usually people do because it will cost you a lot of money to buy it.

2.3 METHOD

2.3.1 BEAM DESIGN

Usually type of the beam that will be tested is flanged and rectangular beam, there also hollow beam but not all construction used it because of the difficulty to create its formwork. Plus the flanged and the rectangular beam are used widely in daily construction because there will sustain more load due to its shape, the properties of it that will the beam stronger.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 BEAM AND DESIGN PROPERTIES.

The type of beam that had been used in my research is rectangular beam. The material that has been used in my research is Ordinary Portland Cement (OPC), mild steel reinforcement, but for the aggregates, it used ratio means there is some sample with aggregates partial polystyrene and for every sample the ratio are different. The beam is lightweight concrete beam because the material that I used in my research which is polystyrene and also called EPS beads. The whole research is about the density of the lightweight concrete which is more lighter than normal beam but can it act as the same or can it sustain the load as much as the normal beam.

3.2 PARAMETER USED FOR TESTING

Type of test that has been conducted for the beam in my research unconfined compression test, deflection and cracking plus the capacity in each beam. The equipment that used in the testing is Magnus Frame.

3.3 SAMPLE OF PREPARING

The size of the beam is 0.15m base x 0.3m height x 2.0m long of the span and was casting 6 sample. Each sample are different from one another because changed the ratio of aggregates in each beam. Means some of the beam contain partial amount of aggregates and polystyrene. The reinforcement that I used is mild steel bar Y12 because of its properties can sustain load as much as normal beam and it also used in daily construction.

And after undergo the normal process of construction beam which is including mixing the concrete, vibrating, curing and then the beam are tested.

3.4 COMPRESSIVE STRENGTH TEST

Most materials have small or large defects in them which act to concentrate the stresses locally, effectively causing a localized weakness. When a material is bent only the extreme fibres are at the largest stress so, if those fibres are free from defects, the flexural strength will be controlled by the strength of those intact 'fibres'. However, if the same material was subjected to only tensile forces then all the fibres in the material are at the same stress and failure will initiate when the weakest fibre reaches its limiting tensile stress. Therefore, it is common for flexural strengths to be higher than tensile strengths for the same material. For a rectangular sample, the resulting stress under an axial force is given by the following formula:

$$\sigma = \frac{F}{bd}$$

This stress is not the true stress, since the cross section of the sample is considered to be invariable (engineering stress).

- F is the axial load (force) at the fracture point
- *b* is width
- *d* is the depth or thickness of the material

3.5 FLEXURAL TEST

Flexural test machine– The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

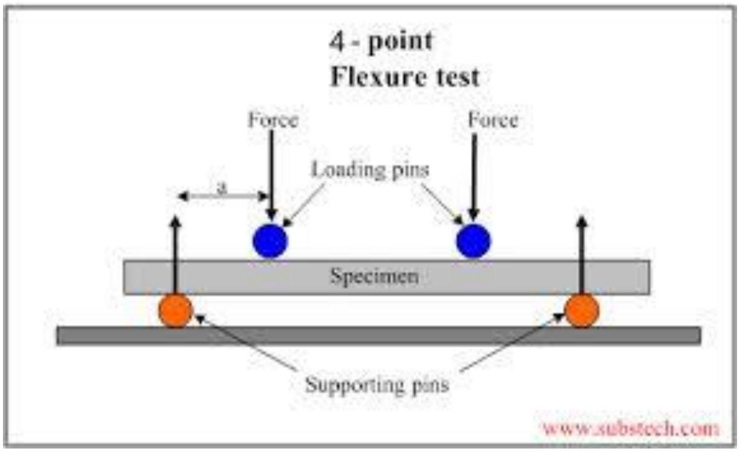

Figure 3.1 Setup for 4 point flexural test

3.6 PROCEDURE

i. Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire cross section of the beam mould and throughout the depth of each layer.

ii. Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.

iii. Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be **3d** and the distance between the inner rollers shall be **d**. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.

iv. The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centred with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.

v. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

3.7 CALCULATION

The Flexural Strength or modulus of rupture (f_b) is given by

$f_b = pl/bd^2$ (when **a** > 20.0cm for 15.0cm specimen or > 13.0cm for 10cm specimen)

or

$f_b = 3pa/bd^2$ (when **a** < 20.0cm but > 17.0 for 15.0cm specimen or < 13.3 cm but > 11.0cm for 10.0cm specimen.)

Where,

a = the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen

b = width of specimen (cm)

d = failure point depth (cm)

l = supported length (cm)

p = max. Load (kg)

3.8 DEFORMATION OBSERVATION

There are several type of cracking that occur in all beams which are the shear stress, bending stress and the compression. At the early stage after the load applied on the beam it begin to crack at the centre of the beam then the crack grow from the centre towards the support means that there is strain stress and shear stress. While for the compression stress start to crack the beam at late stage where the beam want to reach the ultimate load but not all the beam had the tension crack which is the control ratio beam, there is no compression crack. Tension crack occur at the lower part of the beam aligned with the reinforcement inside the beam.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter concentrates towards results obtained from laboratory test including compressive cube test and flexural strength test. The results were analyzed as well as discussed in tables and figures forms. Every test in which have different types of data need to analyze turning it is easier to present and understand. The specimens were cured and tested at 7 and 28 days. The quantity or the ration that had been used are choose from the journal. The information could be very practical for upcoming study and future development of building materials. There are 3 type of test that had been conducted which are compression test, flexural test which is the 4 point loading and lastly is about the cracking pattern to show the behavior and analyses the properties of the EPS beads.

The engineering properties of lightweight concrete using EPS beads as partial replacement of aggregates are presented and discussed throughout this chapter particularly.

4.2 COMPRESSIVE STRENGTH

A compression test determines behavior of materials under cracking loads. The specimen can be compressed and deformation at various loads can be recorded.

From the outcomes of compressive test, the graph of comparison between average compressive strength along with age of sample was carried out. Table 4.1, 4.2, and 4.3 show the compressive test full result for each ration and beam.

Table 4.1 – Ratio Control

Days	Sample	Weight (kg)	Stressed (N/mm²)
7	A	2.0	18.20
	B	2.0	21.05
	C	2.0	19.36
	Average		19.21
28	A	2.20	38.02
	B	2.25	37.4
	C	2.20	36.24
	Average		36.81

From Table 4.1, the 7 and 28 days compressive strength were plotted. Based on compressive strength for control specimen, intended for 7 days, its optimum load was 19.21 N/mm^2 and for 28 days, their optimum load is 36.81 N/mm^2. The gain in strength was higher from the increase in the curing length.

Table 4.2 – Ratio 1

Days	Sample	Weight (kg)	Stressed (N/mm²)
7	A	1.90	14.90
	B	1.90	15.54
	C	1.90	16.16
	Average		15.26
28	A	2.0	29.35
	B	2.0	27.32
	C	2.0	28.10
	Average		28.54

From Table 4.2, Ratio 1 specimens shows optimum load with 15.26 N/mm^2 for 7 days while 28.54 N/mm^2 with respect to 28 days. Analysis from the result shows the increment concrete strength from day 7 until day 28.

Table 4.3 – Ratio 2

Days	Sample	Weight (kg)	Stressed (N/mm²)
7	A	1.60	13.90
	B	1.60	13.74
	C	1.65	14.36
	Average		13.02
28	A	1.8	17.67
	B	1.75	18.32
	C	1.70	18.10
	Average		23.97

From Table 4.6, Ratio 2 specimen shows the best load 13.02 N/mm^2 for 7 days while 23.97 N/mm^2 for 28 days. Although the strength increase from day 7 in order to 28, but the EPS make it less strong compare with the other two ratio.

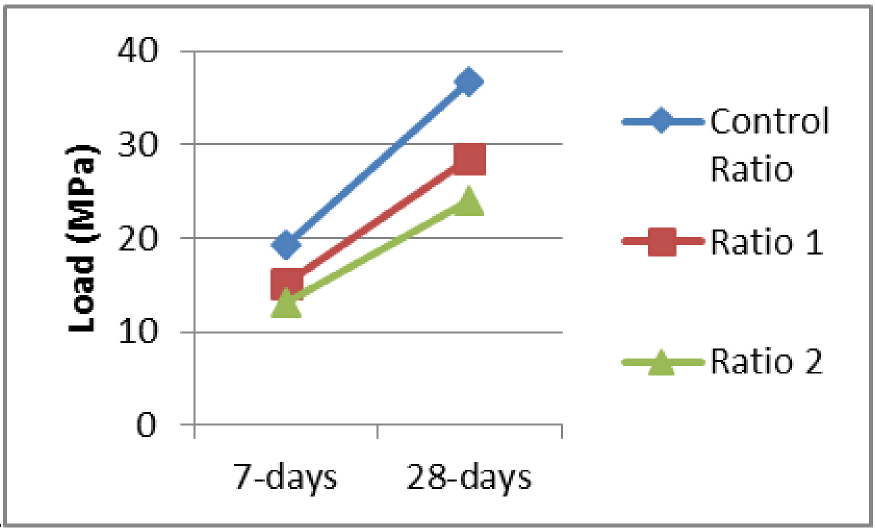

Figure 4.4 Compressive Strength Graph

Refer to the Figure 4.4, the values of compressive are increase for the 3 ratios and Ratio 1 is most likely the theoretical which is less than the ratio control but the value are not so much different. The results for compressive strength show that adding EPS has slight significant effect on compression strength because the shape of the beads that make the bond strong. They may not same as the control but it is most likely in strength. There are several aspects that affected to the result. The real features of the concrete itself have been affected to the result. Some of the aspect may be from the quality of the water when curing process which not clean enough

One of the part that causing insignificant result was the mixture of concrete. During the mixing process, the mixture was not mixed or merges together. When this happens, concrete will be not complete mix with one another and the strength of the concrete become low. It should mix carefully due to lightweight beads plus the beads if not mix properly it will make something like a small ball thus not mix with the other material in the concrete. That's why some of the cubes were tested that had been tested if look closely some of them the beads inside are like gumball that it can be concluded that the EPS may float while hardening.

4.3 Load Deflection (4 –point Loading Test)

The test is most likely the flexural test 3 point loading but for this research it is to determine the deflection and stress of the lightweight beam. There are two (2) batch of mixes of this beam which are effect the result on both mixes.

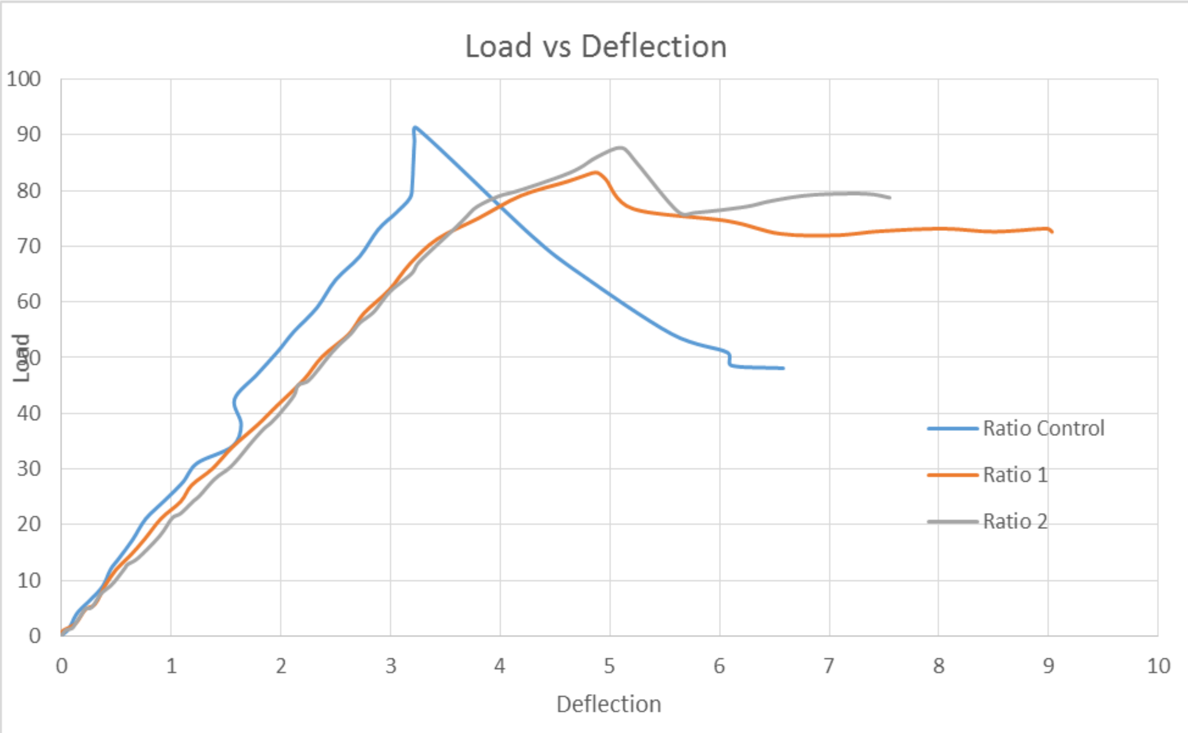

Figure 4.5 - 1st Batch Mix

From the observation the Ratio control had the highest load applied before its failed which the load is 91 kN, followed the ratio 2, 85 kN and lastly ratio 1 which is 83 kN. The graph shows that the ratio control had the highest load applied but after it completely failed different from the other two ratio that not completely failed but remain at certain time. Which can say the polystyrene make the elastic properties of the beam much longer not likely the control which has no EPS beads inside the mixture of the beam.

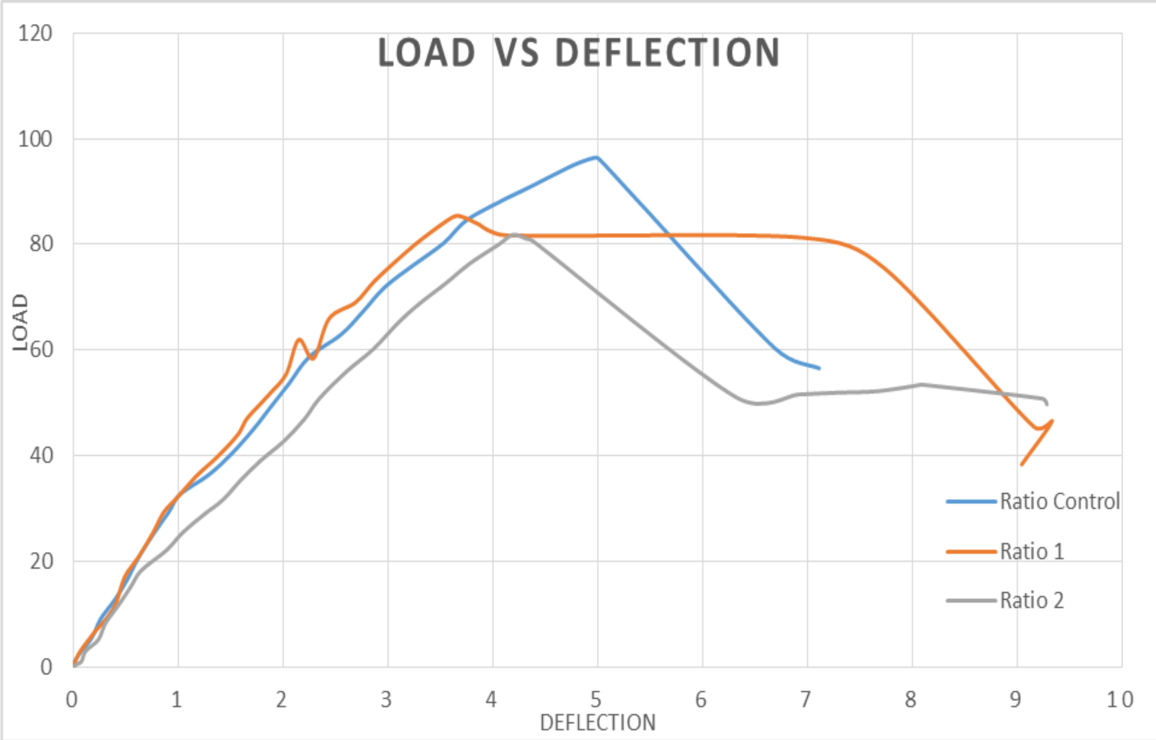

Figure 4.6 - 2nd Batch Mix

From the observation the Ratio control had the highest load applied before its failed which the load is 96 kN, followed the ratio 1, 85 kN and lastly ratio 1 which is 81 kN. The graph shows that the ratio control had the highest load applied but after it completely failed different from the other two ratio that not completely failed but remain at certain time. Which can say the polystyrene make the elastic properties of the beam much longer not likely the control which has no EPS beads inside the mixture of the beam.

Once cracks established, it was noticed that there is a change in load-deflection curve. Before cracking happen the slope was steep and almost linear. The slope also just near to theoretical deflection measured. Both batch are most likely the same. But for the ration control in mix 1 the line totally failed maybe due to improper curing. As summary, the post-crack reduction in load generally decreases as the EPS beads content increases.

4.4 Stress Strain (Reinforcement)

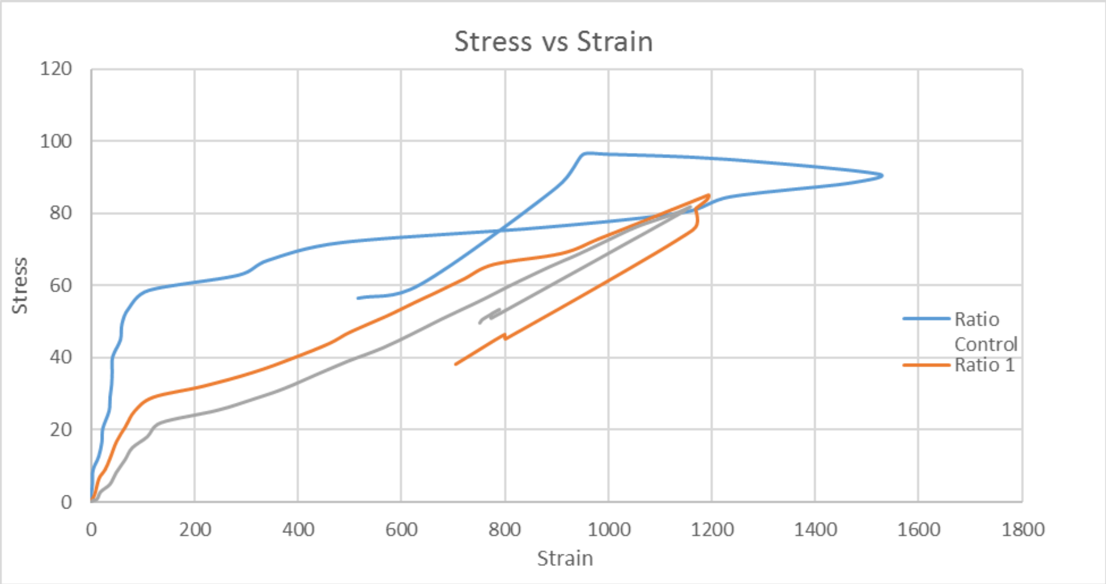

Figure 4.7. Graph Load vs. Strain,

2nd batch mix (Reinforcement at middle)

From the observation we can see that ratio control still remain as the highest strain level before it totally failed at 1500 followed by ratio 1 at 1259 and lastly ratio 2 at 1160. From the graph line it shows that the both ratio most likely the theory which can say that the EPS beads make the elastic properties of the beam stronger so that the graph is linearly increase than failed afterwards. But for the control ration the graph are not likely as the theory maybe because in the beam there is no EPS beads so the elastic properties is lower but the valued still remain as the highest.

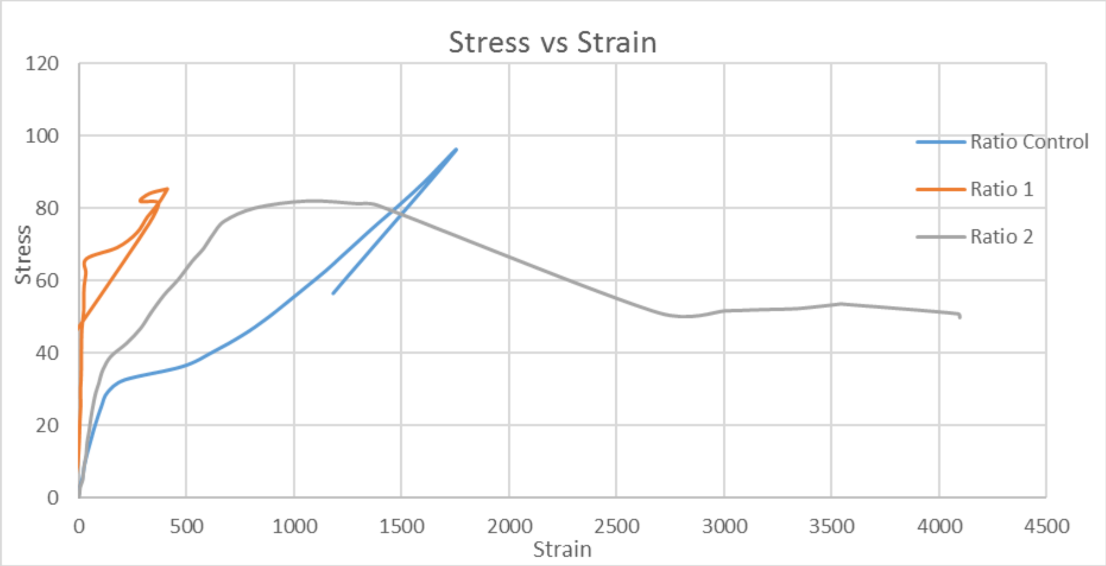

Figure 4.8. Graph Load vs. Strain

2nd batch mix;(Reinforcement at end)

From the graph it shows that ratio control as the highest strain at 1750, followed by ratio 2 and lastly ratio 1. The graph is not likely the strain on the middle reinforcement graph like the previous graph which we can conclude that the end of the 3 beam start to failed are much longer time to take compare at the middle because the load are concentrated mostly on the middle of the beam so the stress are high on that region.

As for the summary we can say that the EPS beads make the elastic properties much longer than the normal beam because the EPS beads. EPS beads are less dense or lighter which may not be high load can be applied but the EPS can hold the beam much longer before its starts to failed.

4.5 Cracking Pattern.

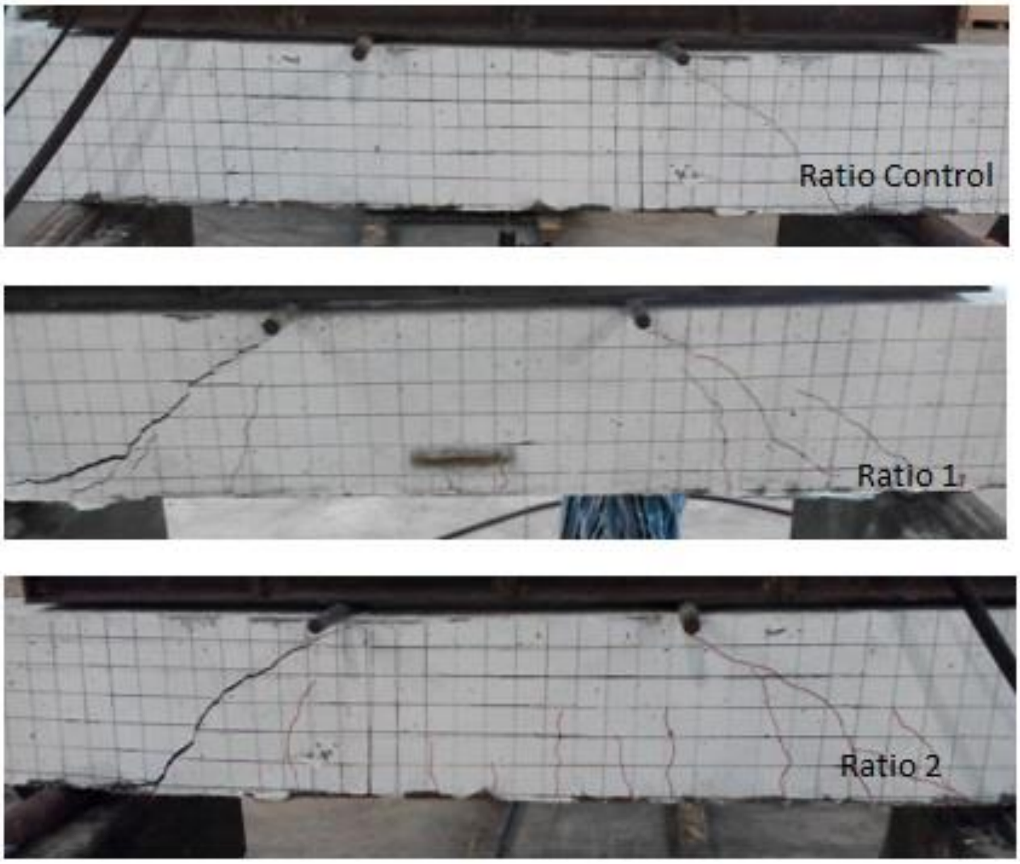

Figure 4.9 Cracking Pattern for 1st batch mix.

From the observation on the figure 4.9 ratio 2 are the most crack occur on the surface on the beam compare to the other two beams which are less. Ratio control had the slightest crack means that these result are likely the theory which on shear stress. Like the two ratio it have compression failure, shear and bending stress crack on the surface due to EPS beads inside these two beams.

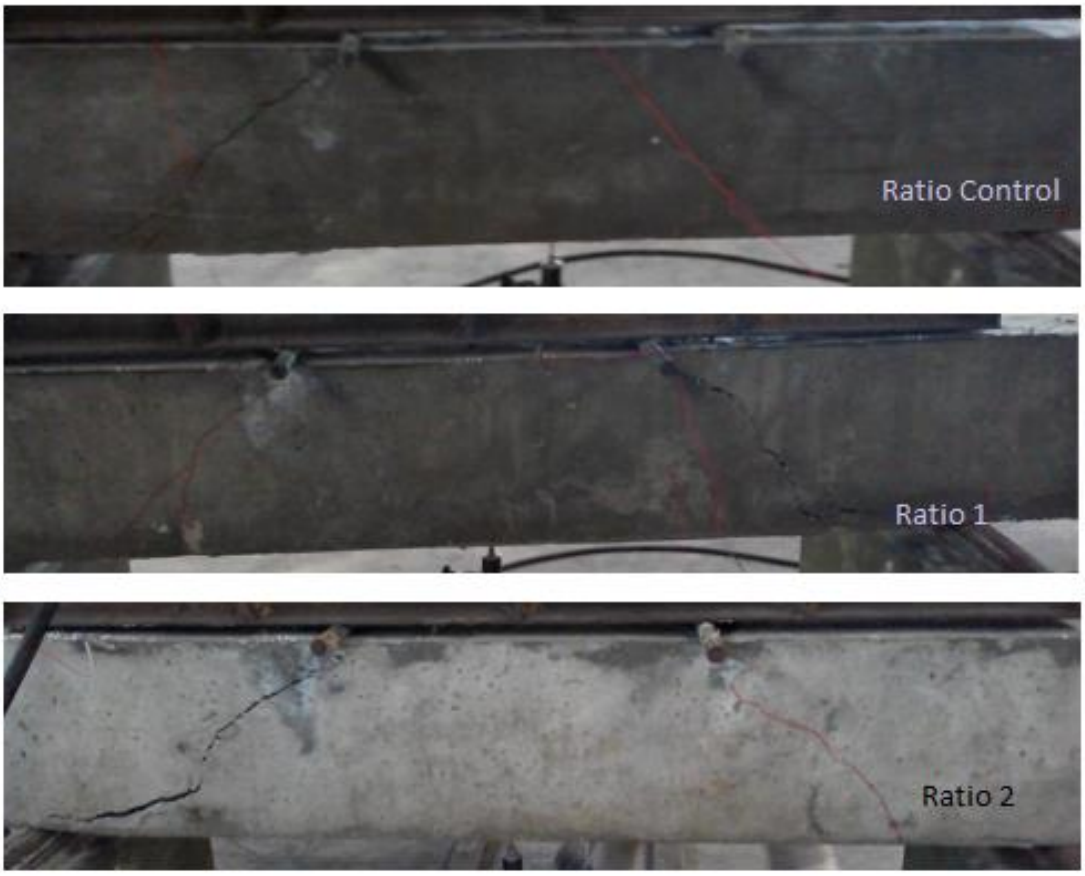

Figure 4.10 Cracking Pattern for 2nd batch mix.

From the observation, ratio control less crack than the other ratio means that it can sustain more load compare the other two before it fails. At the early stage the cracking start from the point of test which in the middle of the beam before it starts to crack to the other two support of the beam. From the figure it shows that ratio 2 has the biggest crack especially when the cracks reaches the support of each beam regardless of 1st batch or 2nd batch mix. It shows that ratio control can sustain high load before its fails plus the cracking also small compared to the other two ratios.

4.6 Conclusion.

Addition of EPS beads inside the normal reinforced beam improves slightly but not the same as the normal reinforced beam because the EPS properties itself. The compressive strength, tensile strength, and flexural strength although it does not improve linearly with increasing in fiber content (percentage). This is due to the amount of void present and the lack of bonding or due to improper curing on all the beam regardless of 1^{st} batch mix or the 2^{nd} batch mix due to added EPS beads. All result that was successfully obtained was shown.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction.

This chapter will discuss the conclusion of this study that is about compressive, flexural behavior of reinforced beam and the cracking pattern of the lightweight reinforced beam added with EPS beads. According to result and analysis from the experimental laboratory testing this chapter will discuss about the result, discussion and conclusion that follows research's objective in Chapter 1.

5.2 Conclusion

i. Polystyrene concrete can be classified as lightweight concrete according to American Concrete Institute (ACI).

ii. The workability characteristics of the mixes are very different from the normal concrete. The mixes were cohesive that the cement slurry coating the beads was very effective in holding the mix together. There is no need for compaction because the properties of the EPS is self-compacted which save more time compare when mixing with normal concrete.

iii. EPS contribute to low weight and low density; it also contributes to the low strength of the specimens. EPS are less strong compare to the normal aggregates because of the lightweight properties of it.

iv. The cracking of the EPS lightweight beam are more likely the normal beam which can conclude the strength is high enough compare to the other lightweight materials. Plus of its lightweight it's easier to handle compare to the normal concrete.

v. From the test carried out Ratio 1 give the max load 84 kN and ratio 2 of 82.5 kN which is lower than ratio control of average 93.5 kN.

5.3 Recommendation

In accomplishing this study, lots of effort has been delivered in order to strive towards goal. It is a normal to face challenges and obstacles during undergoing a study. Many new experiences and knowledge will be acquired through these challenges. In return, we ourselves will be enhanced.

Fine silica fume greatly improved the bond between the EPS beads and cement paste and increased the compressive strength of EPS concrete. In addition, adding steel fibre significantly improved the drying shrinkage

In order to accomplish objective, a number of solution has been figured out to resolve the problem arise. For the future studies several recommendation are proposed of this EPS beads as partial replacement of aggregates. The followings are the recommendations relevant to this topic are:

i- Other properties like toughness and durability of EPS beads need to be studied detailed on how to increase the strength.

ii- More samples needed to be tested to get more reliable result. Two percentages of samples are not enough to get an accurate value.

iii- Change the ratio means mix the EPS beads with the normal aggregates so that it can have the same result mostly like the normal reinforced beam.

iv- Proper curing must be done to achieve adequate result.

v- Added with super plasticizer and increase water cement ratio to get a better result on compressive strength, flexural and improve the bond inside the beam.

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APPENDICES A

CALCULATION FOR CONCRETE MIXING

Ratio Control (1 : 3 : 0)

*for 1 beam only

Beam : 0.15 × 0.3 × 2 = 0.09 m^3

Sand : 1 333.33 kg/m^3

Cement : 1 448.89 kg/m^3

0.09 × 1.3 — 30% wastage

= 0.117 m^3

cement = 0.029 × 1448.89

= 42.02 kg

sand : 0.088 × 1333.33

= 117.33 kg

(+)

water : 0.45 × 42.02

= 18.09

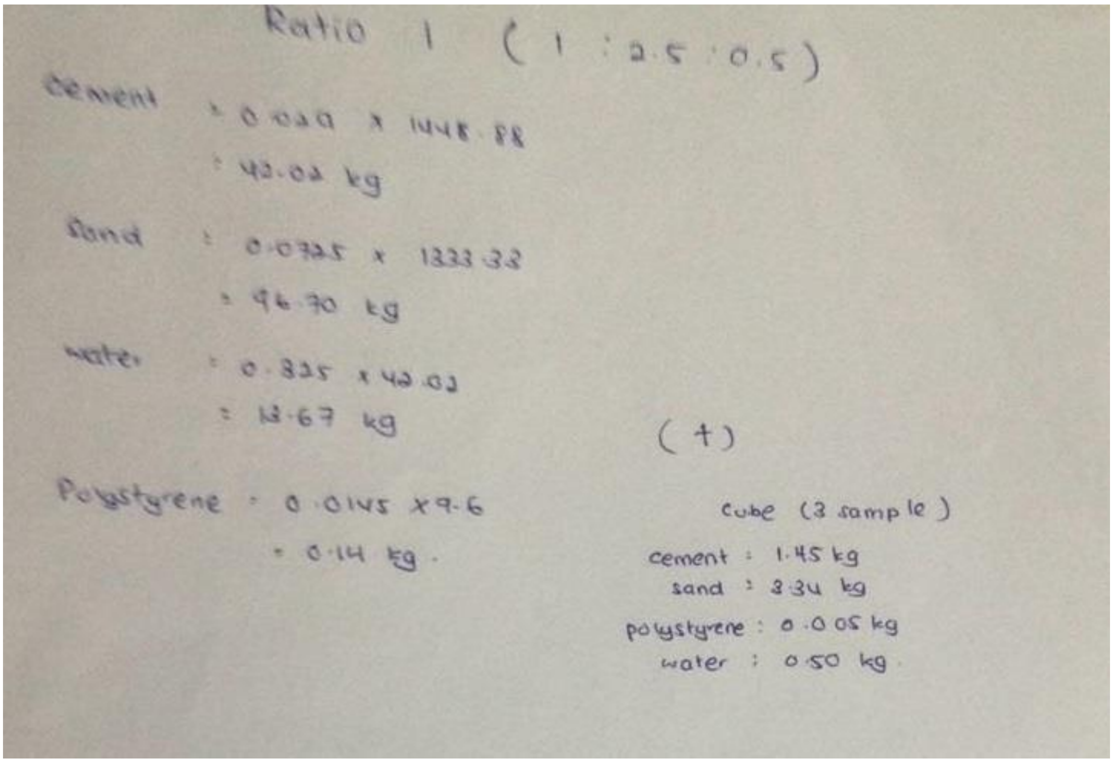
* cube (3 sample)

cement = 1.45 kg

sand = 2.99 kg

water = 0.65 kg.

Ratio Control Calculation.


Ratio 1 (1 : 2.5 : 0.5)

cement = 0.029 x 1448.88
= 42.02 kg

Sand : 0.0725 x 1333.33
= 96.70 kg

water = 0.325 x 42.02
= 13.67 kg

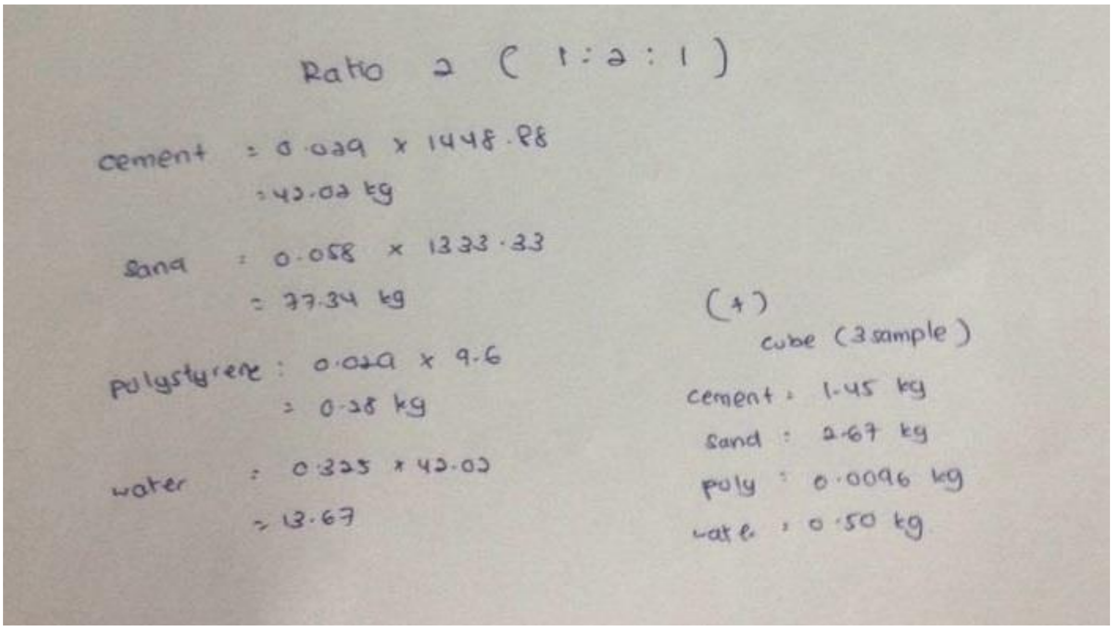
Polystyrene = 0.0145 x 9.6
= 0.14 kg.

(÷)

cube (3 sample)

cement : 1.45 kg
sand : 3.34 kg
polystyrene : 0.005 kg
water : 0.50 kg.

Ratio 1 Calculation.


Ratio 2 (1 : 2 : 1)

cement = 0.029 x 1448.88
= 42.02 kg

sand : 0.058 x 1333.33
= 77.34 kg

polystyrene : 0.029 x 9.6
= 0.28 kg

water : 0.325 x 42.02
= 13.67

(÷)
cube (3 sample)

cement : 1.45 kg
sand : 2.67 kg
poly : 0.0096 kg
wate : 0.50 kg

Ratio 2 Calculation.

APPENDIX B

CUBE TEST

Cubes after Finished Testing.

Compressive Strength Test.

Preparing Sample Before Testing.

Curing Process.