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A STUDY OF FLEXURAL STRENGTH OF RECTANGULAR BEAM USING POLYSTYRENE BEADS AS A PARTIAL REPLACEMENT OF FINE AGGREGATES

NAZATHUL NAJWA BINTI SULAIMAN

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

Faculty of Civil Engineering and Earth Resources
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JUNE 2016

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Dedicated to my beloved parents,

Mr. Sulaiman Long and Mrs. Rohani Razali

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ABSTRACT

Lightweight concrete (LCW) has been successfully used and it is very well known due to its lower density than normal concrete. It is created using materials that has a low density. Nowadays, most studies on LWC more towards about the influence of materials on the strength. Many researchers prove that polystyrene beads one of the best things in lightweight category to combine with concrete. The element that made up from polystyrene beads can involve in structural or non-structural parts. The aim of this study is to produce a lightweight concrete beam that is produced from expanded polystyrene beads as a partially replacement to fine aggregate. In this study, the strength of LCW with different density such as 2077 kg/m^3 for normal concrete, 1344 kg/m^3 for ratio 1, 1664 kg/m^3 for ratio 2 and 1614 kg/m^3 for ratio 3 was produces with different percentage of polystyrene beads as partially replacement of fine aggregates. Four series of LWC mix design including normal concrete with ratio of 3:1:0, ratio 1; 1:2:1, ratio 2; 1:2.5:0.5 and ratio 3; 1:1.5:1.5 which is comprises of 0%, 12%, 25% and 37.5% as partially replacement of fine aggregates (by total weight of fine aggregates) were considered and river sand was used as fines aggregates. There are two types of test were conducted namely compressive strength and flexural strength. The tests were conducted in order to determine the effect of percentage of polystyrene beads due to different curing ages. The results showed that, the increasing the percentage of polystyrene beads as river sand replacement, the strength decreasing significantly due to compressive strength and flexural strength for all mixes. It is also showed that the curing ages crucially affect its strength. Overall, it is indicated that the optimum mix design to produce LWC-Polystyrene Beads was obtained by using 12% of polystyrenes beads as partially replacement of fine aggregate.

ABSTRAK

Konkrit ringin telah digunakan secara meluas dan sangat terkenal dengan ketumpatan yang rendah berbanding dengan konkrit biasa. Ia dicipta dengan menggunakan bahan dari ketumpatan yang rendah. Pada masa kini,kebanyakan kajian di lakukan terhadap konkrit ringan menjurus kepada bahan yang mempengaruhi kekuatan. Ramai penyelidik membuktikan bahawa manik polisterina adalah salah satu bahan di dalam kategori bahan ringan yang sesuai untuk di gabungkan bersama konkrit. Unsur yang terdiri daripada manik polistirena boleh dilibatkan di bahagian-bahagian struktur atau bukan struktur. Tujuan kajian ini dijalankan adalah untuk menghasilkan konkrit ringan yang dihasilkan daripada manik polisterina berkembang sebagai pasir gentian. Di dalam kajian ini, kekuatan konkrit ringan dengan ketumpatan yang berbeza seperti 2077 kg/m^3 untuk konkrit biasa, 1344 kg/m^3 untuk nisbah 1, 1644 kg/m^3 untuk nisbah 2 dan 1614 kg/m^3 untuk nisbah 3 dihasilkan dengan peratusan manik polisterina yang berbeza sebagai pasir gentian. Empat siri konkrit ringan telah dihasilkan termasuk konkrit biasa dengan nisbah 3:1:0, nisbah 1; 1:2:1, nisbah 2; 1:2.5:0.5 dan nisbah 3; 1:1.5:1.5 dimana terdiri daripada 0%, 12%, 25% dan 37.5% sebagai pasir gentian daripada jumlah berat pasir sebenar dan pasir sebenar yang digunakan adalah pasir sungai. Dua jenis ujian telah dijalankan iaitu kekuatan mampatan dan kekuatan lenturan. Ujian ini dijalankan untuk menetukan kesan peratusan manik polisterina dengan masa pengawetan yang berbeza. Keputusan menujukkan bahawa semakin menaik peratusan manik polisterina sebagai pasir gentian, semakin menurun kekuatan kekuatan mampatan dan kekuatan lenturan. Ia juga menunjukkan bahawa peningkatan umur pengawetan akan mempengaruhi kekuatan mampatan konkrit ringan. Secara keseluruhan, didapati bahawa rekabentuk campuran yang optima untuk menghasilkan konkrit ringan dengan manik polisterina adalah campuran yang mengandungi 12% manik polisterina.

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Thesis

The purpose of this thesis is to conduct a study about the flexural strength of rectangular beam using polystyrene beads as course aggregate. All the steps and procedure are shown in this thesis. At the end of this research, all the objectives should be answered and proved. If the testing result is slightly different from the theoretical or expected, the reasons are stated in the discussion.

1.2 Introduction to Lightweight Concrete

For over fifty years, there are many attempts to overcome the disadvantages of concrete in making building. Concrete is well known as heavy, rigid and its thermal and acoustical quality is not very high. In order to overcome this issue, one of the ways is by replacing aggregate of concrete, sand or gravel with lighter materials. First natural products were utilized such as corn, pumice, schist, cork, pozzuoluna and woods. Later knowledge and insulation concerns more materials were used including expanded clay, vermiculite, expanded glass, aluminum, expanded rock and expanded polystyrene (EPS). Polystyrene is best known for its efficiency, cost-effectiveness and lightweight. Polystyrene meets all the requirement of economical packaging and consequently its waste mounted day after day. Polystyrene is vinyl polymer produced by free radical vinyl polymerization. While expandable Polystyrene (EPS) is polystyrene in raw beads being steam-heated, causing it to expand and forming a cellular structure. They are many names for polystyrene such as "styropor" and mainly used as insulating materials. The beads are inelastic so they do not recover when deformed but still able to withstand the stresses when the concrete is mixed.

Lightweight concrete (LWC) being one of the choices in construction industry because of its advantage in terms of economic and also it is practical. It is convenient to categorize the various types of lightweight concrete by their method of production. These are; (i) by using porous lightweight aggregate of low apparent specific gravity. (ii) By introducing large voids within the concrete or mortar mass. (iii) By leave the fine aggregate from the mix so that a large number of interstitial; voids are present; normal weight course aggregate is generally used.

Lightweight concrete also has a small density compare to normal concrete because of the presence of voids. Obviously, it is clear that the presence of these voids will leads to decreasing in strength of lightweight concrete compared with normal weight concrete. Furthermore, it will reduce the cost of formwork and steel and also increase productivity. Concrete which has lower density also gives better thermal insulation compare to normal concrete. Many lightweight concrete has been produced by using lightweight aggregates (LWA) and artificial aggregate such as fly ash, slag and porcelinite rocks and mostly the process of manufacturing lightweight concrete is costly. This leads to using polystyrene beads as an alternative way. Polystyrene beads are choosing because of its light density about (16-27) kg/m^3, good thermal energy absorbing characteristics and good thermal insulator. Some researchers conduct the study about the structural, physical and mechanical behavior of polystyrene concrete. During the manufacturing of polystyrene concrete, they avoided vibration and compact their mixes by hand tamping. This is done to reduce the segregation of polystyrene beads because of its low density.

So, the main objectives to carried out this experiment is to use polystyrene beads to produce special type of concrete mixture characterized by high resistance to segregation that can be cast without compaction or vibration due to compacted self-weight. Polystyrene concrete is a lightweight concrete made with expanded polystyrene beads usually known for its good thermal and caustic insulation properties. Several researchers that studied the properties of polystyrene concrete like density, compressive and flexural strength, dynamic modulus of elasticity and thermal conductivity. This results show that the properties are affected by the polystyrene concrete and decreases with increase the polystyrene cement ratio.

A study of concrete using polystyrene beads as replacement of course aggregate was carried out by Park and Chisholm [3]. Three different density were conducted and at each density, mixes both with and without fly ash were examined. It was found that the polystyrene concrete is very prone to segregation and also it has a low compressive strength. It also has relatively high drying shrinkage. For thermal conductivity testing showed that the lighter the concrete, the lower the thermal conductivity. By adding flying ash to the mixes, it will decreased the water demand thus, the density and shrinkage but also caused a significant compressive strength reduction. While Sussman [9] concluded that the mechanical properties of polystyrene concrete is increase with the increase of density and these properties are controlled by the water to cement ratio. Maura [10], also produced polystyrene concrete with densities between (220-460) kg/m^3 and compressive strength between (0.7-2.3)MPa, while modulus of rapture was between (0.3-0.36)MPa. Ismail[4] studied the properties of hardened concrete bricks containing polystyrene beads and he found that polystyrene concrete is very prone to segregate where placing and compacting can be quite difficult using vibratory compaction techniques. He also found that polystyrene concrete bricks with densities less than 1800kg/m^3 have very low strength which is suitable to use as load bearing internal wall.

Flexural strength also known as modulus of rupture, bend strength or fracture strength. Flexure tests are generally used to determine the flexural modulus or flexural strength of a material. For method of testing, we used four point load method to test the flexural test. The four points bending flexural test provides values for the modulus of elasticity in bending, flexural stress, flexural strain and the flexural stress-strain response of the material. The main advantage of a four point flexural test is the ease of the specimen preparation and testing. Flexure test is run until the sample experiences failure and is therefore ideal for the testing of brittle materials. The most common materials tested in flexure are plastic materials, composites, concrete, and ceramics. Because these materials have a very low ductility they will break before any permanent deformation of the sample occurs allowing for the accurate measurement of the flexural modulus and strength. Unreinforced concrete beam is concrete without reinforcement. Beam is a long, sturdy piece of squared concrete spanning an opening or part of building.

1.3 Problem Statement

To study the flexural strength on unreinforced concrete beam using polystyrene beads as aggregate. One of the major issues in constructing beam is the bending or deflection problem. As we know concrete is good in compression while poor in tension. One of the ways to overcome the problem is inserting the reinforcement bar to withstand the tension in concrete. This is also known as reinforced concrete. So, for that we study unreinforced concrete in order to test the behavior of the materials subject either polystyrene is better than aggregate or not we should undergo flexural test on the beam using polystyrene beads as aggregate.

1.4 Objectives

The objectives of this study are to:

1. To study about the flexural stress.
2. To measure the properties of polystyrene concrete beam.

1.5 Scope of Study

Mixed design for prepare the sample is referred from Lect. Manolia Abed Al-Wahab Ali (Al-Muntansiriya University) and the sample is prepared according to the ratio from the journal that consist of 4 experimental ratio with Portland cement which is 1:3 that act as control, 1:2.5:0.5 which is ratio 1, 1:2:1 which is ratio 2 and last ratio is 1:1.5:1.5. The ratio polystyrene is increases as the ratio of sand is decreases while the ratio for cement is fixed. The sample of beam size is 150 x 150 x 750 is tested under four point load test for measured its flexural strength. The test is carried out after 14 days and 28 days of curing. In addition, for compressive test, the cube is tested after 7 days, 14 days and 28 days of curing.

1.6 Significance of Study

This study is important in determining the flexural strength of unreinforced concrete beam in which the ratio of sand is replaced with polystyrene beads. In construction field, costing is important. So, in order to reduce costing in construction, one of the ways is to reduce cost in material. Polystyrene beads are cheap and it is easy to get from factory plus the density is low thus reducing the weight of the concrete.

CHAPTER 2

LITERATURE REVIEW

2.1 General

2.1.1 High Strength Concrete

There is no specific definition of high strength concrete. The definition is relative. It is depends on a period of time and location. For example, in 1960s, a concrete with a 28-day compressive strength at least achieved 42MPa is considered as high strength concrete. While, in 1950s, concrete that achieved 35MPa is already considered as high strength concrete. This day, generally concrete that achieved 60MPa with minimum 28-day compressive strength is classified as high concrete strength although concrete with compressive strength excess of (70MPa) can be achieved. In early 1970s, the practical limit would not exceed a compressive strength more than 76MPa as predicted by experts. Nevertheless, over the past 20 years, the development of high strength concrete could achieve a concrete with compressive strength 131MPa of two buildings in Seattle, Washington. The American Concrete Institute defines high strength concrete as concrete with compressive strength more than 41MPa, while medium strength concrete (conventional concrete) in the range of 21-41MPa (Tengku Fitriani L.,Subhan,2006).

2.1.2 Application of lightweight concrete

The reasons we used lightweight structural concrete in construction is because of its high strength properties. Shells and roofs are among the particular types of structures that can be built systematically with lightweight strong concrete. There are many types of aggregates that can be used to produce lightweight concrete such as expanded shales, polystyrene beads, clays, slates, slag and pumice or scoria, which are naturally existing volcanic aggregates. The choice of material used is depends on availability of lightweight materials. In San Miguel, espumilla orarenilla which is a type of pumice is locally available that is used to produce a lightweight concrete for walls and roofs. Lightweight concrete having a good resistance to heat and sound was used as soundproofing material in subway stations (Tengku Fitriani L., Subhan, 2006)

While in Germany, they used ‘no-fines aggregates’. In this concrete, the aggregate cord-holes are covered with a thin cement paste layer and bonded together at point-to-point cement contacts (Short, A. and Kinniburgh, W., 1978). In Hong Kong, four types of lightweight concrete that are commonly used are autoclave aerated concrete (plus lime), autoclave aerated concrete (plus fly ash), concrete with synthetic aggregate ‘Leca’ (light expanded clay aggregate) and concrete with polystyrene beads (reddiform.com, 2004). Armenia is situated in an earthquake region. So, Armenian engineers decided to use lightweight concrete in their construction of building because lightweight concrete reduce the density of concrete in order to reduce the mass of the structure therefore, can reduce the lateral forces. Besides that, High Performance Lightweight Concrete is proved by demonstrated it for offshore platforms, which are currently used by many countries such as Japan, USA, UK, Canada, Norway and Australia (Malhotra, V.M., 1995), (Tengku Fitriani L., Subhan, 2006).

2.1.3 Application of lightweight high concrete strength

In North America, high strength lightweight concrete with compressive strength ranging from 35 to 55 MPa has been used widely about forty years by North American precast and prestressed concrete producers (Shah, S.P. and Ahmad, S.H., 1994). The use of high strength building in Australia is at Melbourne Central – 70 MPa at 56 days, The Rialto Project and Shell house – both are 60 MPa at 56 days (Mak, S.L., Darvall, P.L.P., and Attard, M.M., 1989). In Japan, Asia, they used high strength concrete for producing prestressed concrete girders of bridges to reduce dead load and to get longer span with compressive strength above 49 MPa as required by Japanese Industrial Standard (JIS) (Shah, S.P. and Ahmad, S.H., 1994). Bridges that used high strength concrete are Dai-ni-Ayaragigawa Bridge, Ootanabe Bridge, Iwahana Bridge, Kazuki Bridge and Akkagawa Bridge. On other hand, in Indonesia, they generally used conventional concrete and high strength concrete is not commonly used due to earthquake factor and also cost-effective. However, they still use it but limited to the metropolitan areas like Jakarta and Surabaya which is applied in high-rise buildings. Therefore, the use of lightweight concrete is quite important and very useful because polystyrene aggregate concrete has better energy-absorbing capacity which would be beneficial in structures which are likely to be imposed to earthquake.

In Norway, high strength concrete has been used for offshore exploitation of petroleum resources in the North Sea since 1973 (Rønnerberg, H. and Sandvik, M.). Lightweight high strength concrete is needed in the marine structures due to mostly offshore concrete structures are constructed in shipyards which is located in lower latitudes and then floated and towed to the project site. So, it is need to reduce weight and increase the structural efficiency of cast-in-place structure (Shah, S.P. and Ahmad, S.H., 1994), (Tengku Fitriani L., Subhan, 2006).

2.2 Materials

2.2.1 Cement

There are many types of cement that can be used to produce lightweight concrete mixes. For example one of the types of cement used is type GP (S.G. Park and D.H. Chischolm, 1999). Another example of cement used in another research about these studies is general purpose of ordinary Portland cement. Its chemical and physical properties comply with the Iraqi specification NO.5/1984 (Lect.Manolia Al-Wahab Ali, 2012). Besides that, Israeli company, had manufactured ordinary Portland cement, “Nesher” with fly ash up to 10% of cement weight and comply with ASTM C150. This is the type of cement that only available in Gaza (Z.Kuhail and S.Shihada, 2003).

Table 2.1: Mechanical Properties of cement

Type of cement	Test		Result
A	Compressive Strength (MPA)	3-day	-
		7-day	0.5 - 3.2
C	Compressive Strength (MPA)	3-day	19.7
		7-day	25.1

* A = Cement type GP (S.G. Park and D.H. Chischolm, 1999).
C = Nesher with fly ash up to 10% and comply with ASTM C150 (Z.Kuhail and S.Shihada, 2003).

Figure 2.1: Ordinary Portland cement

2.2.2 Fine Aggregate

The fines aggregate used throughout these studies is natural siliceous desert sand and it is comply with the requirement of the Iraq specification NO.46/1984, zone (2) (Lect. Manolia Abed Al-wahab Ali, 2012). While another researcher's use sand. This sand have finesses modulus FM = 2.68 (Z.Kuhail and S.Shihada, 2003).

Figure 2.2: River sand

2.2.3 Polystyrene Beads

The polystyrene beads used are raw fire retardant and containing an expending agent. In order to form a cellular structure, these beads are subjected to steam to expand. After expand, the beads are left out in the air for few hours before being used in the mix to allow the pressure between the beads to match with the outside air. The expanded beads have an apparent density of 16.5 kg/m^3 with diameters 4 mm. It is used as partial replacement of fine aggregate (K.L.Lai and R.Sri Ravindrarajah, 1996). Some researchers use expanded beads that have an apparent density of 16-27 kg/m^3 and diameters ranging from 1.5 to 3.0 mm (Z.Kuhail and S.Shihsada, 2003).

Figure 2.3: Polystyrene beads

2.2.4 Water cement ratio

According to journal ‘Deformation Behavior of Reinforced Polystyrene Concrete Beam’ the polystyrene aggregate concrete mixture had the water to cement ratio of 0.44 compared to the normal weight concrete which is 0.62. In order to achieve the strength same as normal concrete, the water cement ratio in polystyrene aggregate concrete is decreases (K.L.Lai and R.Sri Ravindrarajah, 1996).

Table 2.2: Water cement ratio.

Researchers				
A	W/C ratio	0.44		
B	Sample	1	2	3
	W/C ratio	0.35	0.40	0.45

* A = Polystyrene Aggregate Concrete (K.L.Lai and R.Sri Ravindrarajah, 1996).
B = Polystyrene-lightweight Concrete (Z.Kuhail and S.Shihsada, 2003).

2.3 Method

2.3.1 Beam Design

For main tension reinforcement for concrete beam that have reinforced, two 16 mm diameter high-tensile steel (yield stress – 450Mpa) bars were used. For compression zone, 10 mm bars mild-steel bars were used at the ends of the beams. For testing flexural strength, the beam is slowly tested in increasing flexural strength until failed. To monitor the deflection of the beams at the mid-point during the test at each load increment, monitor is used and data logger is used to record the deflection during the test (K.L.Lai and R.Sri Ravindrarajah, 1996).

2.3.2 Lightweight Concrete Density Design

The presence of polystyrene beads make the workability of the lightweight concrete decrease, thus, superplasticizer was used to increase the workability. So, the workability of polystyrene aggregate concrete is better than the normal weight concrete due to the use of superplasticizer. Besides that, the uses of a low amount of water which is 195kg/m^3 compared to normal aggregate which is 235kg/m^3 make the workability of the lightweight concrete decrease. The polystyrene aggregate concrete used cement and fly ash as a binder and have density 555kg/m^3 while the normal weight concrete is 380kg/m^3. Overall, the unit weight of polystyrene aggregate concrete is 2160kg/m^3 while the normal weight concrete is

2405kg/m^3. Therefore, the polystyrene aggregate concrete is 10% much lighter compared to the normal weight concrete (K.L.Lai and R.Sri Ravindrarajah, 1996). By table 3, for researchers B (Z.Kuhail and S.Shihada, 2003) after the aggregate content is chosen together with the cement content and the water cement ratio for each sample, the polystyrene beads is determined by subtracting the total volume of water, cement and aggregate from the unit volume, set as 1m. The final result density for thirty-six out of all the mixes of polystyrene-lightweight concrete is around 948.08 kg/m^3 to 1680.15 kg/m^3 (Z.Kuhail and S.Shihada, 2003).

Table 2.3: Composition of Concrete Mixes.

Researchers	**Materials**	**Limits**		
A	W/C ratio	0.44		
	Cement (kg/m^3)	445		
	Fine Aggregate (kg/m^3)	670		
	Course Aggregate ((kg/m^3)	750		
	Polystyrene bead (kg/m^3)	5.45		
	Superplasticizer ((kg/m^3)	3.1		
	Fly Ash (kg/m^3)	110		
B	Sample	1	2	3
	W/C ratio	0.35	0.40	0.45
	Cement (kg/m^3)	350	400	450
	Aggregate (kg/m^3)	500	750	1000
	Polystyrene bead (m/m)	0.30 – 0.70		

* A = Polystyrene Aggregate Concrete (K.L.Lai and R.Sri Ravindrarajah, 1996)
B = Polystyrene-lightweight Concrete (Z.Kuhail and S.Shihada, 2003)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is shows about the process used to collect data for the purpose of making analysis data in Chapter 4. It is means that in this chapter are showing, the actual procedure that are carried out in the concrete laboratory in order to collect data. The procedure shows from the beginning process such as preparing the sample and formwork, during the process like curing and during the testing. Flow chart below shows the work need to do in order to get the result.

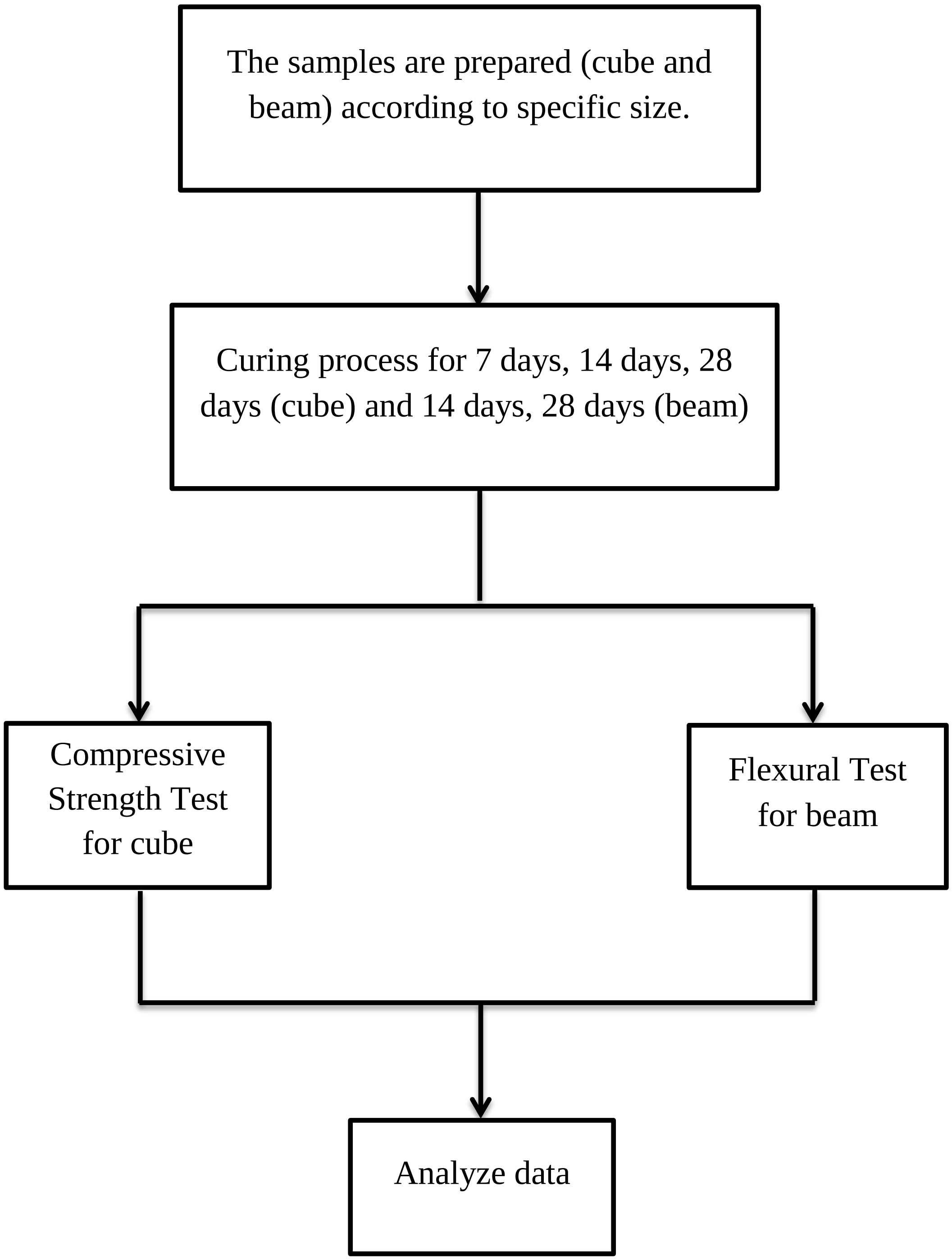

Figure 3.1: Flow chart for laboratory work

3.2 Beam and Design Properties

First of all, the size that is used in these studies is 150mm x 150mm x 750mm. Beam that are cast is unreinforced polystyrene concrete beam and it is casting in a plywood mould. The design of beam is shown as in figure 3.2. There are many types of cement that can be used, but for these studies, the cement that is used is ordinary Portland cement that is available in concrete lab at Universiti Malaysia Pahang (UMP).

The other materials that are used are fine aggregate which is river sand and also expanded polystyrene beads as a replacement to the course aggregate. No plasticizer and other additive mixtures were used in these studies in order to produce the basic concrete which forms by cement, water and aggregate. The modifying part is just the replacement of expanded polystyrene beads. This is because the main aim of this research is to produce lightweight polystyrene concrete unreinforced beam using basic element of normal concrete.

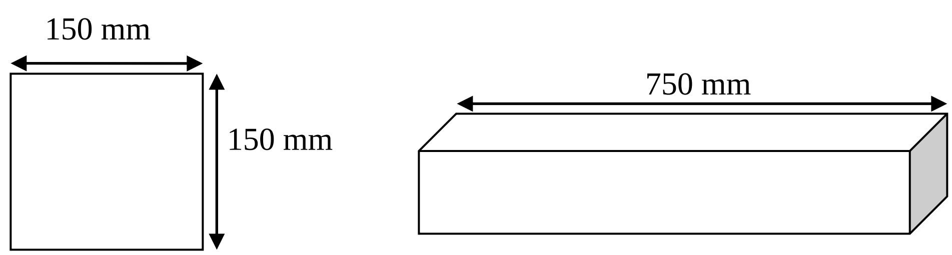

Figure 3.2: Dimension of beam

3.3 Parameter used for testing

Instruments that are used for this research is compressive machine for Compressive Strength Test and U-Test machine for Flexural Test and deflection test. This machine is available in the concrete lab and will be conducted by the technician.

Figure 3.3: Compression Test Machine

Figure 3.4: U-Test Machine for flexural test

3.4 Sample of preparing

For preparing the sample, the proportions of concrete mix used is (1:3:0) by volume of (cement: sand: polystyrene) with cement content of 300 kg/m^3 and water. Cement ratio for control mix is 0.45. From the control mixes, three different samples of polystyrene concrete will be prepared. The different is by a vary content of a partial replacement of sand with polystyrene beads. Because of the beads is very light in weight and density, so it is prepared by volume. Table 4 below shows the proportion of mixes that are used throughout this research.

Table 3.1: Details of mixes

Mix symbol	Mix proportions ratio* (C:S:P) by volume	Cement content kg/m^3	W/C** ratio by weight
R	1:3:0	300	0.450
A	1:2.5:0.5	300	0.325
B	1:2:1	300	0.325
C	1:1.5:1.5	300	0.325

*C: S: P = cement : sand : polystyrene beads
**W/C = water/cement ratio

3.4.1 Method for sample preparing

i. Prepare a formwork according to specification sample. For this sample the required size are 150mm x 150mm x 750mm. The formwork is prepared for 24 beams, using plywood.

Figure 3.5: Formwork

ii. Before mixed the mortar, prepared the materials according to the required weight. The materials that need to calculate is cement, river sand, polystyrene beads and also water.

iii. After weighing the materials, the next step is mixing the materials to form mortar. The materials is put into the mixer to gives the constant mix.

Figure 3.6: Mixed the material in the mixer

iv. After put all the materials inside the mixer, let the materials mix for about 5 minutes until the desire texture of concrete comes out. Within the time, prepare the formwork by oiling the formwork using hydraulic oil. Oiling will prevent the concrete from sticking with the formwork when hardening. So, it will not damaged the concrete surface when remove it.

Figure 3.7: Oiling the formwork using hydraulic oil

v. After finish mixing the materials, pour the mixture into the tray. For make it easier, scoop the concrete and put in the bucket or wheelbarrow to pour in the formwork.

Figure 3.8: Scope the concrete into the bucket

vi. For making a cube sample, the layer must be compacted layer by layer to prevent concrete cube from honeycomb when hardening. The sample is compacted using stamping rod.

Figure 3.9: Compact the concrete using stamping rod

vii. After, finish prepares the cube sample, let the concrete hardening in room temperature before remove the mould.

Figure 3.10: Cube sample

viii. For beam sample, using the same method, poured the concrete into the formwork and using the stamping rod, the concrete is compacted to prevent honeycomb.

Figure 3.11: Process for making beam sample

ix. After finish the previous step, let the concrete hardening before remove the formwork

Figure 3.12: Beam sample

x. After one day, remove the cube mould and put the cube in the curing tank before test the cube using compressive strength machine to test the compression strength for 7 days, 14 days and 28 days.

Figure 3.13: Curing process for cube sample

xi. Same for the beam sample, the formwork is removed one day after the casting day. After that, the beam is curing using gunny sack before the beam is test for flexural test for 14 days and 28 days.

Figure 3.14: Curing process for beam sample

3.5 Compressive Strength Test

Compressive strength test is the most common test done by engineers in designing building and structures. The compressive strength is measured by breaking down the concrete specimen in a compression machine specially design for concrete and is known as cube test. The result from compressive strength is used to determine that the concrete mixture is following the requirements of the specified strength or not.

The test was carried out according to BS. 1881: part 116:1989 by using 100 mm cube. The average of three specimens of same ratio is taken as compressive strength of the polystyrene concrete. The test is carried out after 28-days of water curing. The method for testing compressive strength on cube is shown in the flow chart below.

The value of compression strength is defined as shown as:

$$\sigma = \frac{F}{A} \qquad \text{(Eq. 3.1)}$$

Where:

σ = Stress in Mpa

F = Load applied in N

A = Area in meter square

3.5.1 Procedure for Compressive Strength Test

The flow chart below shows the procedure to determining the compressive strength of the cube sample of the concrete.

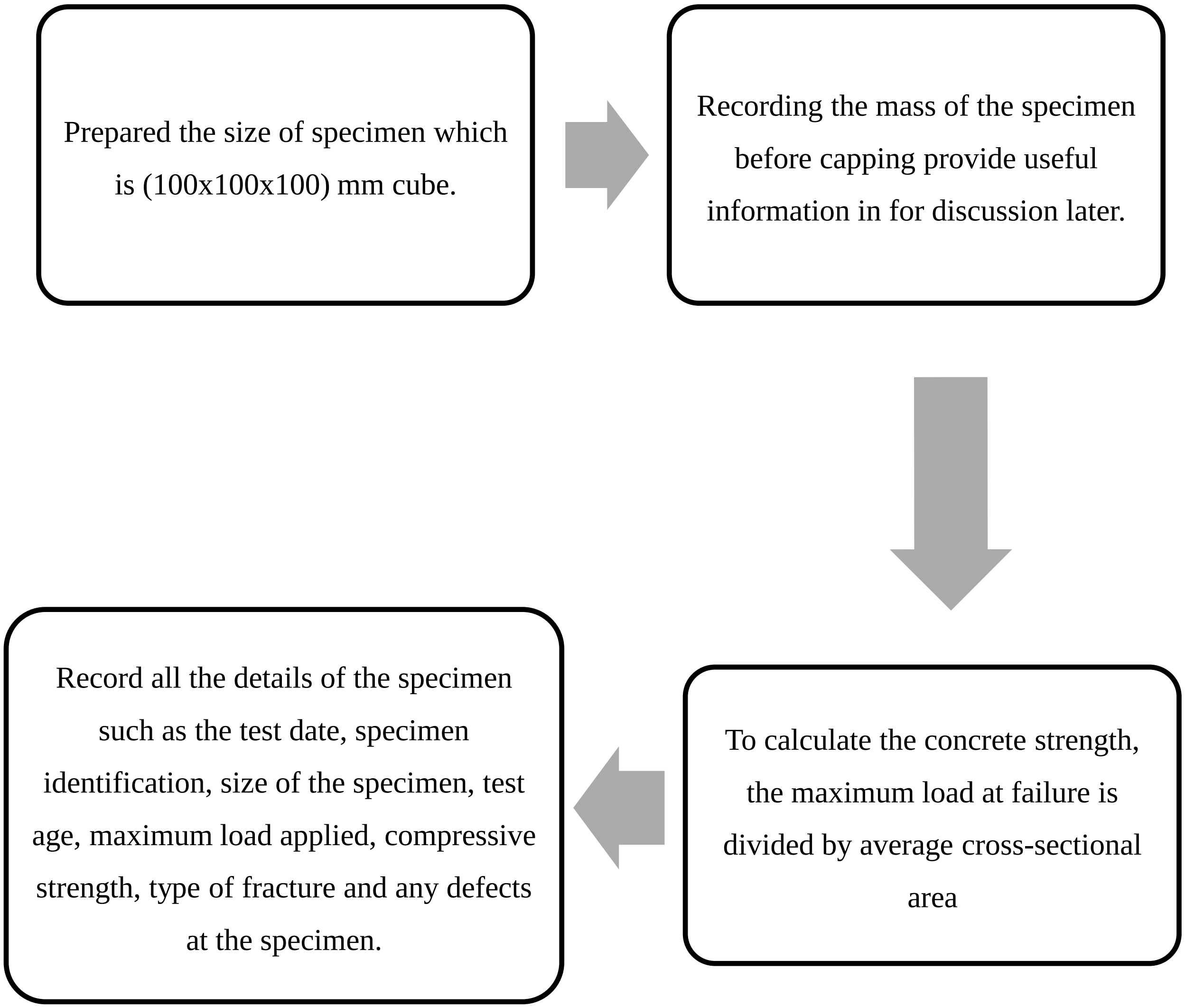

Figure 3.15: Method for testing compressive strength

Procedure below shows the actual step that carried out in the laboratory for compressive strength.

i. Take out the cube sample from curing tank and weigh the cube to get the wet reading and record.

Figure 3.16: Weighing the cube

ii. Let the cube air-dry for about 3 hours until it fully dry and weigh once again to obtain the dry reading and record.

Figure 3.17: Dry-air process

iii. Place the cube in the compression test machine and setting the machine according to the required data that need to obtain before compression test begin.

Figure 3.18: Settings the machine

iv. The compression test will stop when the strength of cube is obtained. The readings are recorded.

Figure 3.19: Record the data

v. After the test is completed, the cube is weigh once again and the cube can be destroyed.

Figure 3.20: The cube after test

3.6 Flexural Test

Flexural strength is carried out to determine the tensile strength of concrete. It is measure of an unreinforced concrete beam to resist failure in bending. This test is carried out according to ASTM (C 78-02 by using (150x150x750) mm prism specimens**.** The prisms were subjected to four point load. Results that are calculated after this test are reported as modulus of rupture. Flexural modulus of rupture is about 10 to 20 percent from the compressive strength depends on its type, size, and volume of course aggregate or in this case volume of polystyrene used. Flexural test is very sensitive to specimen preparations, handling and curing procedure.

The modulus of rupture is calculated as follows:

$$R = \frac{3PL}{4bd^2} \qquad \text{(Eq. 3.2)}$$

Where:
R = Modulus of rupture in MPa
P = Maximum applied load indicated by the testing machine in N
L = Span length in mm
b = Width of specimen in mm
d = Depth of specimen in mm

3.6.1 Method for Flexural Test

Flow chart below shows the procedure to determining the flexural strength of the sample.

Prepare the beam sample as required size.

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.

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.

The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal

Figure 21: Method for Flexural Test

Procedure below shows the actual step that carried out in the laboratory for flexural test**.**

i. Firstly, prepare the sample for testing. Put the sample on the trolley.

Figure 3.22: Prepared the sample

ii. After that, weighing the all beam sample and record the data.

iii. Next step, measure and using marker marking the length of the load that will be place on top of the beam and the length of the support that will be placed on bottom of the beam.

Figure 3.23: Marking the length

iv. After marking the length, placed the beam in the machine to be testing.

Figure 3.24: Placed the sample correctly

v. The testing is conducted by the technician and the tests are carried out until the beam fractured and repeated for all beams sample.

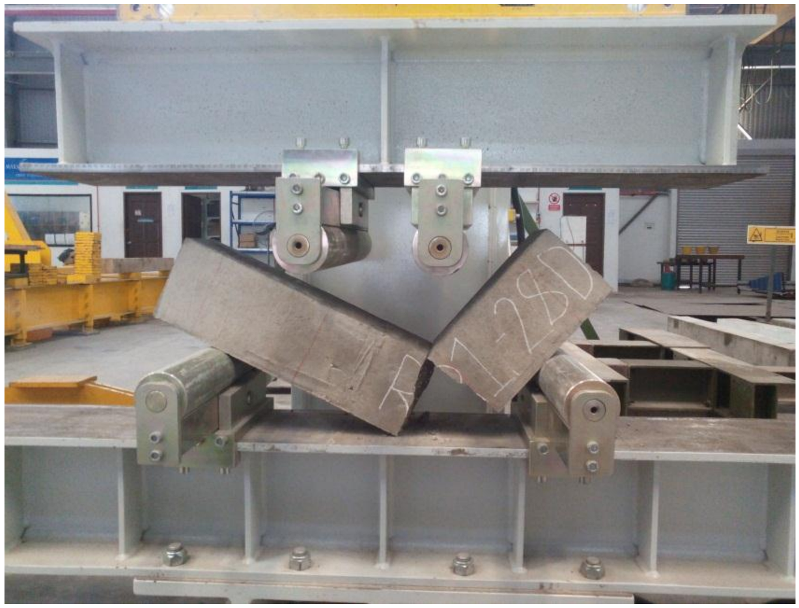

Figure 3.25: Load is stop applied when sample failed

vi. The data that shows on the machine screen are recorded.

Figure 3.26: Data shown on the screen

CHAPTER 4

RESULT & DISCUSSION

4.1 Introduction

Result and discussion is a process after conducting a test or experiment. The result and discussion is gather and analysis and turn into more simple and easy data to understand by the readers such as graph, bar chart, pie chart or table according to the suitability. Result get is a proved either test conducted is successful or not. If the reading get is not as predicted, the probability reasons for the result get is stated in the discussion.

4.2 Compressive Strength

Compression testing is a very common testing method that is used to establish the compressive force or crush resistance of a material and the ability of the material to recover after a specified compressive force is applied and even held over a defined period of time. Total samples for compressive strength test is 32 cubes which means 3 samples for each days and each ratio. They have size 100mm x 100mm x 100mm. The test is conducted in the concrete laboratory, UMP.

Table 4.1: Maximum load and maximum strength at 7-days

	Max. Load (kN)	Max Strength (MPa)
Control	170.097	17.010
Ratio 1	166.961	16.695
Ratio 2	127.840	12.784
Ratio 3	125.626	12.562

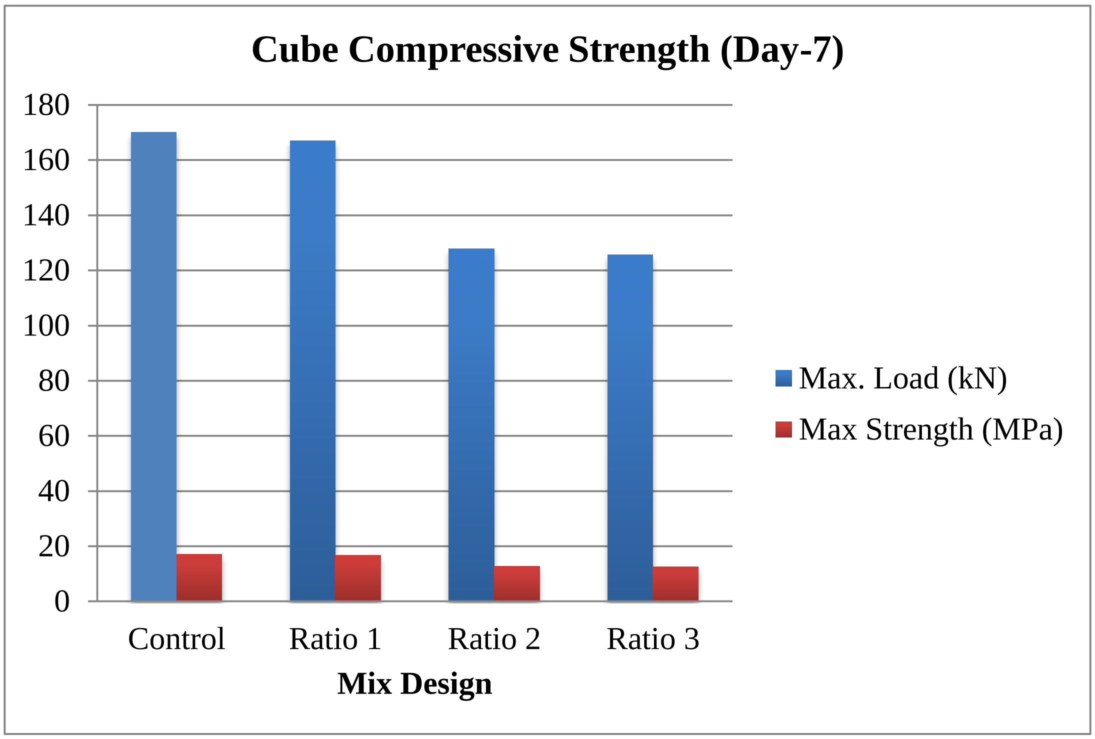

Figure 4.1: Graph of maximum load and maximum strength

The bar chart above shows the comparison between maximum load and maximum strength for control, ratio 1, ratio 2 and ratio 3 for compressive strength test at days 7. As can see, the highest value for maximum load on days 7 is on control which is 170.097 kN and as same as for maximum strength which is17.010 MPa. Control acts as a reference beam sample. This is because the control sample consists 0% of polystyrene beads. Thus, it is increase the strength of the concrete. As for ratio 1, ratio 2 and ratio 3, the maximum load and maximum strength is decreasing by ratio. This is because the percentage of polystyrene is increasing by ratio. For ratio 1, the ratio of cement to sand to polystyrene beads is

1:2.5:0.5 by volume while for ratio 2 are 1:2:1 by volume and for ratio 3 is 1:1.5:1.5 by volume. The value of maximum load that applied on ratio 1 sample which contains 12.5% polystyrene beads is 166.961 kN while the maximum strength is 16.695 MPa. For ratio 2 which contain 25% of polystyrene beads in concrete gives the value of maximum applied load, 127.840 kN and maximum strength, 12.784 MPa and for ratio 3 which contain 37.5% of polystyrene beads gives value of maximum load, 125.616 kN and maximum strength 12.562 MPa which is both the value is the most lowest value of maximum load and maximum strength compare to control, ratio 1 and ratio 2. The pattern of the graph which is decreasing by the ratio is following the pattern of the expected results.

Table 4.2: Maximum load and maximum strength at 14-days 14

	Max. Load (kN)	Max Strength (MPa)
Control	220.86	22.086
Ratio 1	180.373	18.037
Ratio 2	136.404	13.595
Ratio 3	143.026	14.319

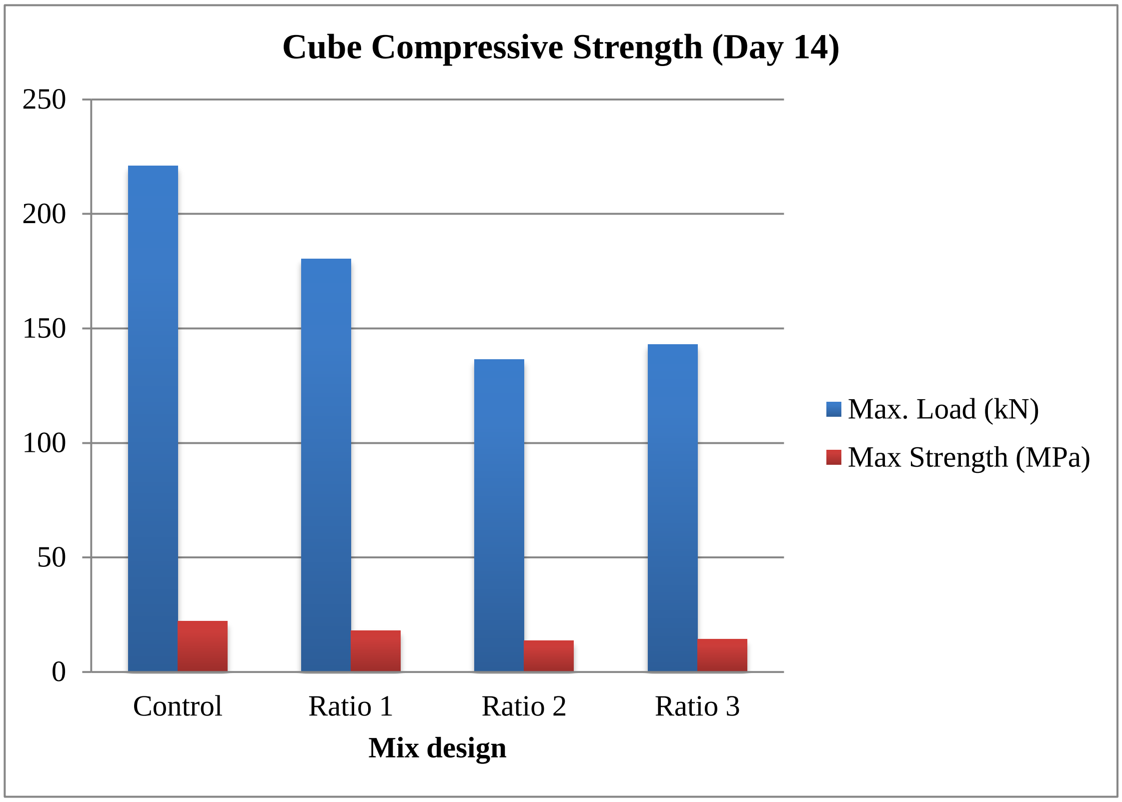

Figure 4.2: Graph of maximum load and maximum strength

The bar chart above shows the comparison between maximum load and maximum strength for control, ratio 1, ratio 2 and ratio 3 for compressive strength test in days 14. As shown above, the highest value for maximum load on days 14 is on control which is a reference beam sample and the value is 220.86 kN and for maximum strength is 22.086 MPa. As for ratio 1, ratio 2 and ratio 3, the maximum load and maximum strength is decreasing by ratio. This is because the percentage of polystyrene is increasing by ratio. For ratio 1, the ratio of cement to sand to polystyrene beads is 1:2.5:0.5 by volume while for ratio 2 are 1:2:1 by volume and for ratio 3 is 1:1.5:1.5 by volume. The value of maximum load that applied on ratio 1 sample which contains 12.5% polystyrene beads is 180.373 kN while the maximum strength is 18.037 MPa. For ratio 3 which contain 37.5% of polystyrene beads gives value of maximum load, 143.026 kN and maximum strength 14.319 MPa and for ratio 2 which contain 25% of polystyrene beads in concrete gives the value of maximum applied load, 136.404 kN and maximum strength, 13.595 MPa which is both the value is the most lowest value of maximum load and maximum strength compare to control, ratio 1 and ratio 3. Supposedly, the value of maximum load and maximum strength is affected by the percentage of polystyrene beads in the concrete sample. This means that, the lowest value of maximum load and maximum strength is from ratio 3 but it turns out that sample from ratio 2 get the lowest value of maximum load and maximum strength. This problem may be due to the sampling is not place accurately during the test. Other than that, it could be during weighing the polystyrenes, the value is not accurate because of the polystyrene is light in weight and it may affect the percentage of polystyrene beads inside the concrete from the actual calculation. When compared with the control sample the pattern of the graph which is decreasing are following the pattern of the expected results.

Table 4.3: Maximum load and maximum strength at 28-days

	Max. Load (kN)	Max Strength (MPa)
Control	374.774	37.478
Ratio 1	223.955	22.395
Ratio 2	181.404	18.141
Ratio 3	165.453	16.545

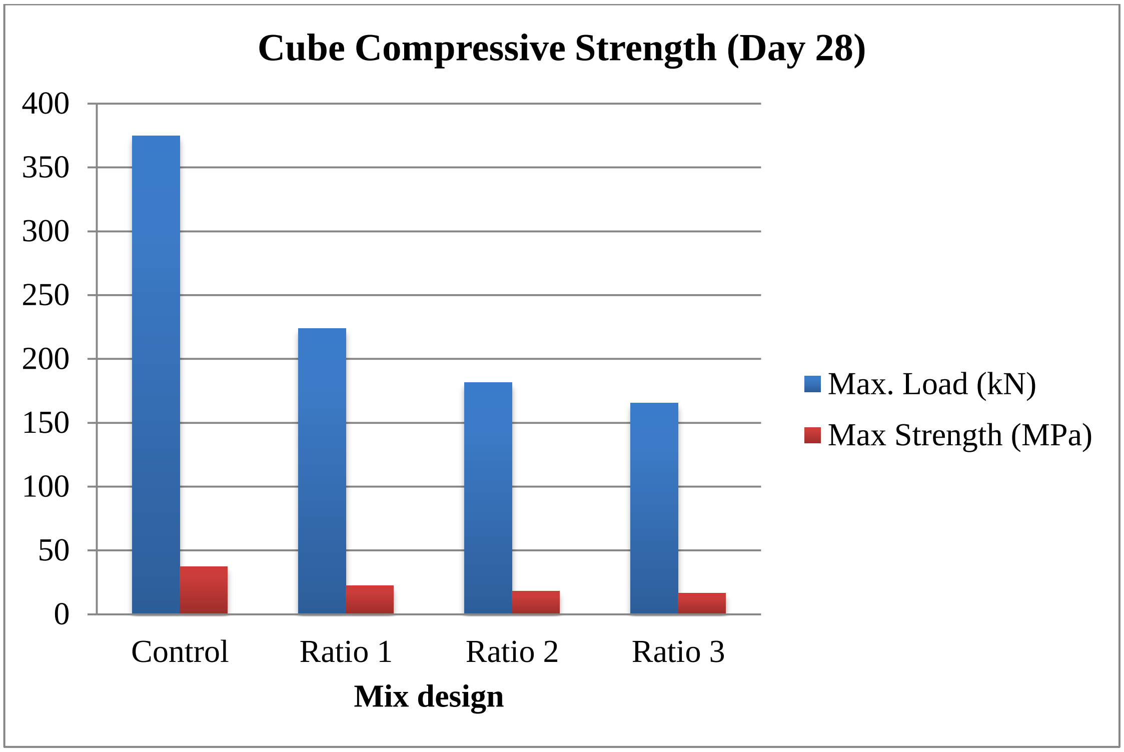

Figure 4.3: Graph of maximum load and maximum strength

The bar chart above shows the comparison between maximum load and maximum strength for control, ratio 1, ratio 2 and ratio 3 for compressive strength test in days 28. As shown above, the highest value for maximum load on days 14 is on control which acts as a reference sample. The reading is 374.774 kN for maximum load and for maximum strength is 37.478 MPa. While for ratio 1, ratio 2 and ratio 3, the maximum load and maximum strength is decline by ratio due to the percentage of polystyrene is increasing. The value of maximum load that applied on ratio 1 sample which contains 12.5% polystyrene beads is 223.955 kN while the maximum strength is 22.395 MPa. For ratio 2 which contain 25% of polystyrene beads gives value of maximum load, 181.404 kN and maximum strength 18.141 MPa and for ratio 3 which contain 37.5% that is the highest percentage of polystyrene in the concrete mixture gives the value of maximum applied load, 165.453 kN and maximum strength, 16.545 MPa which is both the value is the most lowest value of maximum load and maximum strength compare to control between ratio 1, ratio 2 and ratio 3. The value of maximum load and maximum strength is affected by the percentage of polystyrene beads in the concrete sample. The higher the percentage of polystyrene beads in the concrete, the lower the maximum load and maximum strength the concrete. The actual results are still according to the expected results which are decreasing by the ratio.

Table 4.4: Maximum load and maximum strength for control

	Max. Load (kN)	Max Strength (MPa)
Days 7	170.097	17.010
Days 14	220.860	22.086
Days 28	374.774	37.478

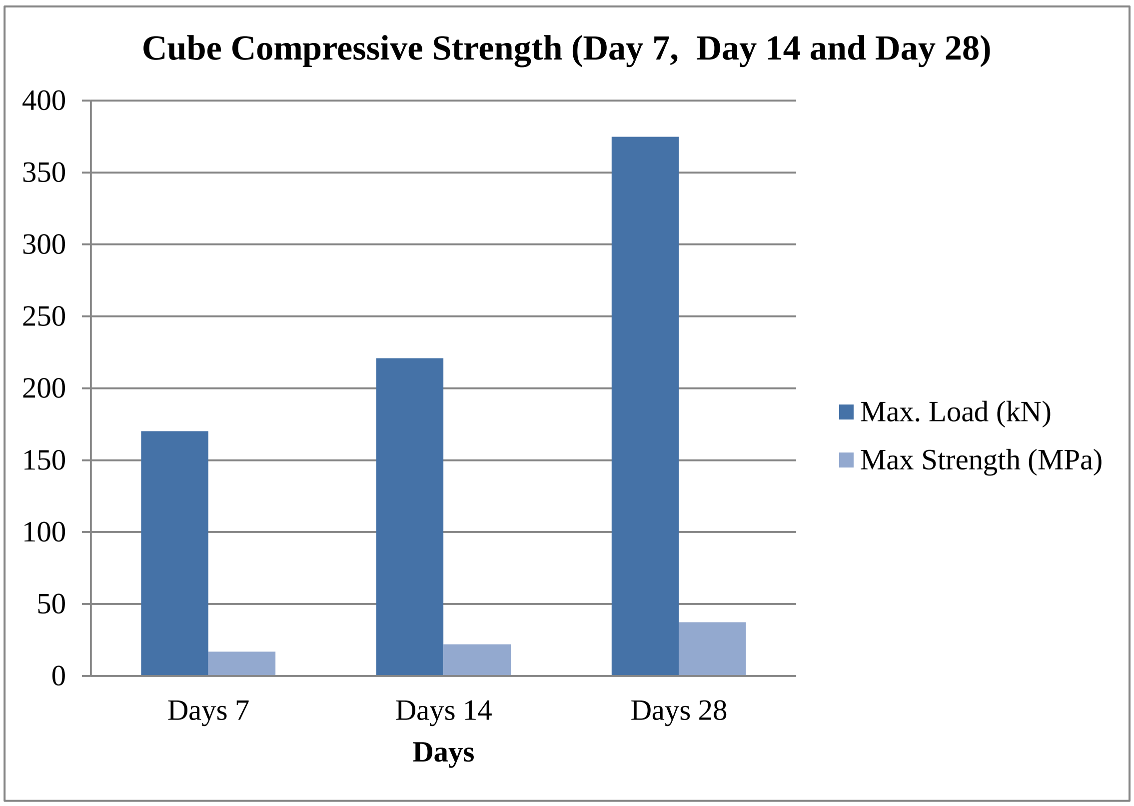

Figure 4.4: Graph of maximum load and maximum strength for control.

The bar chart above shows the comparison between maximum load and maximum strength for days 7, days 14 and days 28 for control sample. Each day consists of 3 samples and the average values get shown on the above bar chart. As expected, the highest value for maximum load for control sample is on days 28 which is 374.774 kN and for maximum strength also from the control sample which is 37.478 MPa. While for the days 14 sample the maximum load applied is 220.86 kN while the maximum strength is 22.086 MPa and for days 7 gives the value of maximum applied load, 170.97 kN and maximum strength, 17.010 MPa. As can see here, the higher the days or the longer the process of sample are curing, the higher the maximum load and maximum strength that the sample will get. This is because curing is the process of maintaining moisture levels inside concrete so that hydration can continue. Hydration is an action of adding water to Portland cement and will start a chemical reaction. As long as free moisture and unhydrated cement exist inside the concrete, the strength, hardness and density will gradually increase. Practically speaking, curing is simply the process of keeping the hardened concrete moist so that it can continue to gain strength. As the concrete gets stronger and denser, its porosity decreases. If the concrete dries out, it stops gaining strength. The pattern of the actual result which is increasing by the days is following the pattern of the expected results.

Table 4.5: Maximum load and maximum strength for ratio 1

	Max. Load (kN)	Max Strength (MPa)
Days 7	166.961	16.695
Days 14	180.373	18.037
Days 28	223.955	22.395

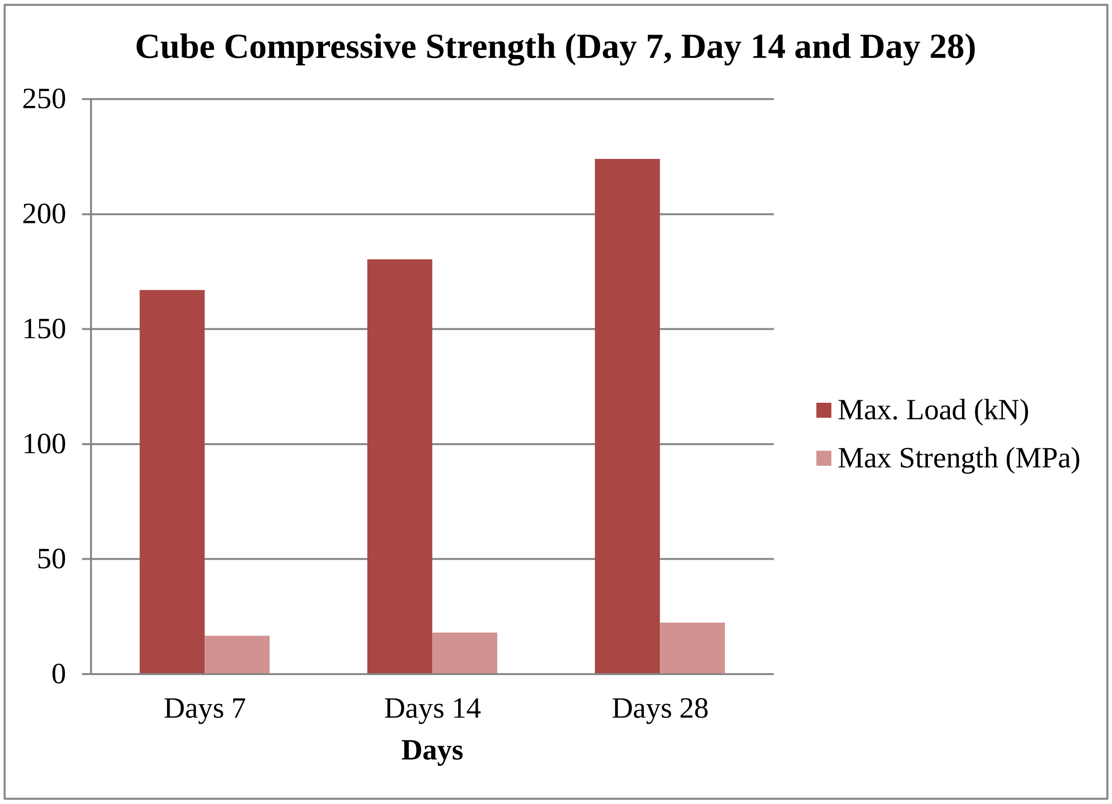

Figure 4.5: Graph of maximum load and maximum strength for ratio 1.

The bar chart above shows the comparison between maximum load and maximum strength for days 7, days 14 and days 28 for ratio 1 sample. Each day consists of 3 samples and the average values get shown on the above bar chart. As expected, the highest value for maximum load for ratio 1 sample is on days 28 which is 223.995 kN and for maximum strength is 22.395 MPa also from days 28. While for the days 14 sample, the maximum load applied is 180.373 kN while the maximum strength is 18.037 MPa and for days 7 gives the value of maximum applied load, 166.961 kN and maximum strength, 16.695 MPa. Days 7 has the lowest value of the maximum load and maximum strength compare to days 14 and days 28. As can see here, the higher the days or the longer the period of sample is curing, the higher the maximum load and maximum strength that the sample will gained. This is because the longer the period of curing process helps the concrete to gained more the strength of concrete. As the concrete gets stronger and denser, its porosity decreases. This is important, because early on the concrete is much more porous than when it is older and has hydrated longer. Porous concrete loses moisture to evaporation quickly, and this can lower internal moisture levels and stop hydration. If the concrete dries out, it stops gaining strength. The pattern of the actual result which is increasing by the days is still following the pattern of the expected results.

Table 4.6: Maximum load and maximum strength for ratio 2

	Max. Load (kN)	Max Strength (MPa)
Days 7	127.840	12.784
Days 14	136.404	13.595
Days 28	181.404	18.141

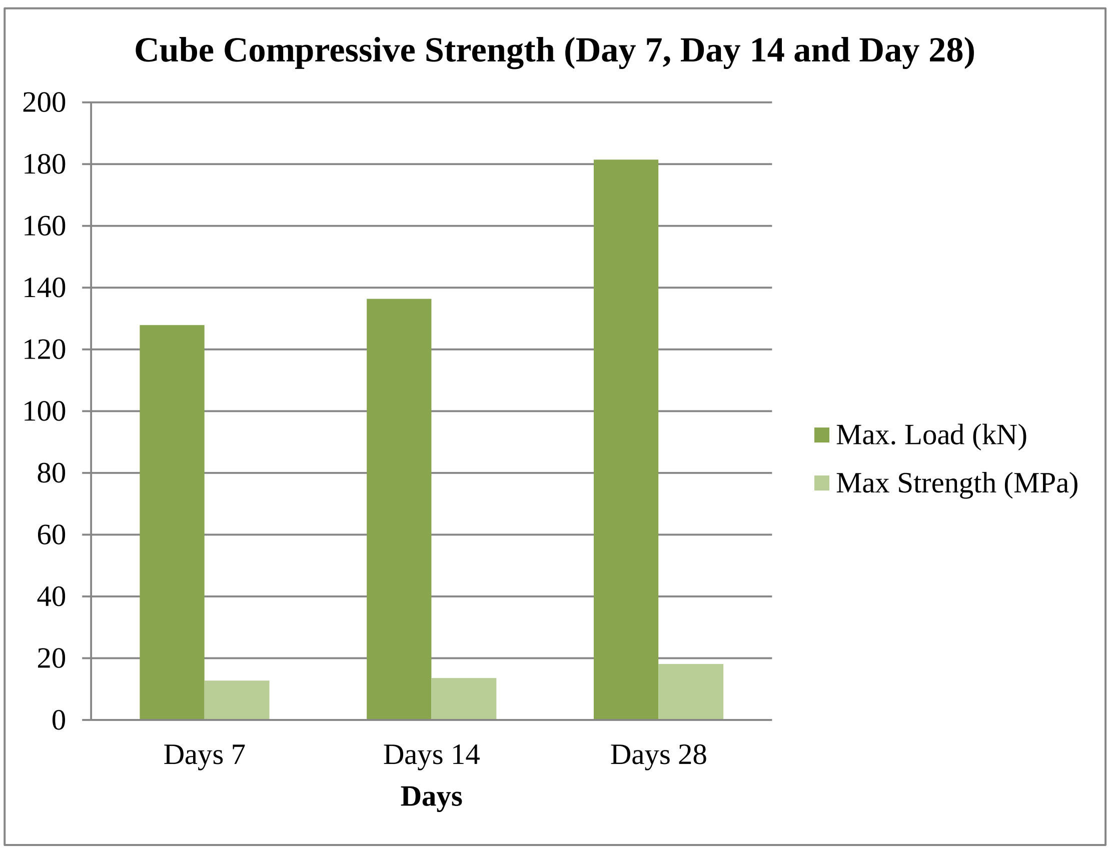

Figure 4.6: Graph of maximum load and maximum strength for ratio2.

Figure 4.6 above shows the comparison between maximum load and maximum strength for days 7, days 14 and days 28 for ratio 2 sample. Each day consists of 3 samples and the average values get shown on the above bar chart. As expected, the highest value for maximum load for ratio 2 sample is on days 28 which is 181.404 kN and for maximum strength also from days 28 which is 18.141 MPa. While for the days 14, the maximum load applied is 136.404 kN while the maximum strength is 13.595 MPa and for days 7 gives the value of maximum applied load, 127.840 kN and maximum strength, 12.784 MPa. Days 7 has the lowest value of the maximum load and maximum strength compare to days 14 and days 28. As can see here, the higher the days or the longer the period of sample is curing, the higher the maximum load and maximum strength that the sample will gained. This is because the longer the period of curing process helps the concrete to gained more the strength of compressive strength. The strength of the concrete is affected by the period of curing process and the pattern of the actual result which is increasing by the days is still following the pattern of the expected results.

Table 4.7: Maximum load and maximum strength for ratio 3

	Max. Load (kN)	Max Strength (MPa)
Days 7	125.626	12.562
Days 14	143.026	14.319
Days 28	165.453	16.545

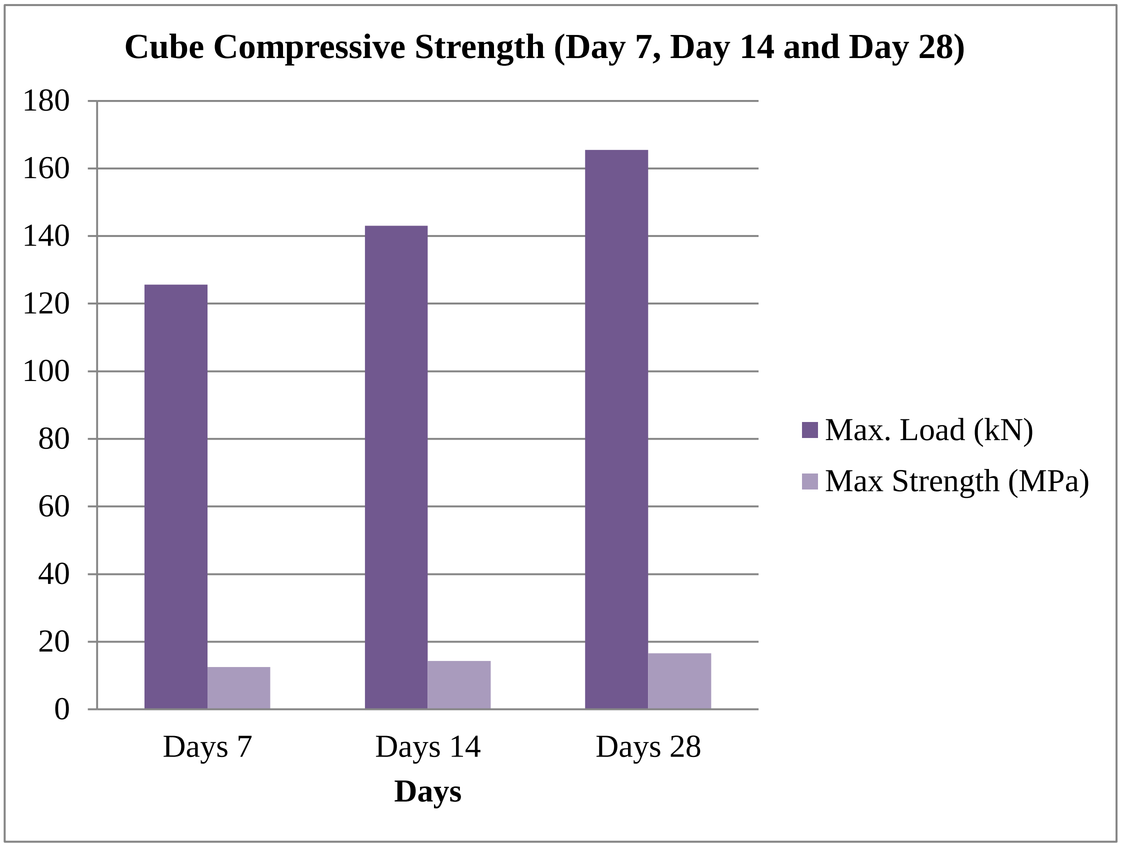

Figure 4.7: Graph of maximum load and maximum strength for ratio 3.

The bar chart above shows the comparison between maximum load and maximum strength for days 7, days 14 and days 28 for ratio 3 sample. Each day consists of 3 samples and the average values get shown on the above bar chart. As expected, the highest value for maximum load for ratio 3 sample is on days 28 which is 165.453 kN and for maximum strength also from days 28 which is 16.545 MPa. While for the days 14 sample, the maximum load applied is 143.026 kN while the maximum strength is 14.319 MPa and for days 7 gives the value of maximum applied load, 125.626 kN and maximum strength, 12.562 MPa. Days 7 has the lowest value of the maximum load and maximum strength compare to days 14 and days 28. As can see here, the higher the days or the longer the period of sample is curing, the higher the maximum load and maximum strength that the sample will gained. This is because the longer the period of curing process helps the concrete to gained more compressive strength. The strength of the concrete is affected by the period of curing and the pattern of the actual result which is increasing by the days is still following the pattern of the expected results.

Table 4.8: Maximum load at 7-days, 14-days and 28-days

	Days 7	Days 14	Days 28
Control	170.097	220.860	374.774
Ratio 1	166.961	180.373	223.955
Ratio 2	127.840	136.404	181.404
Ratio 3	125.626	143.026	165.453

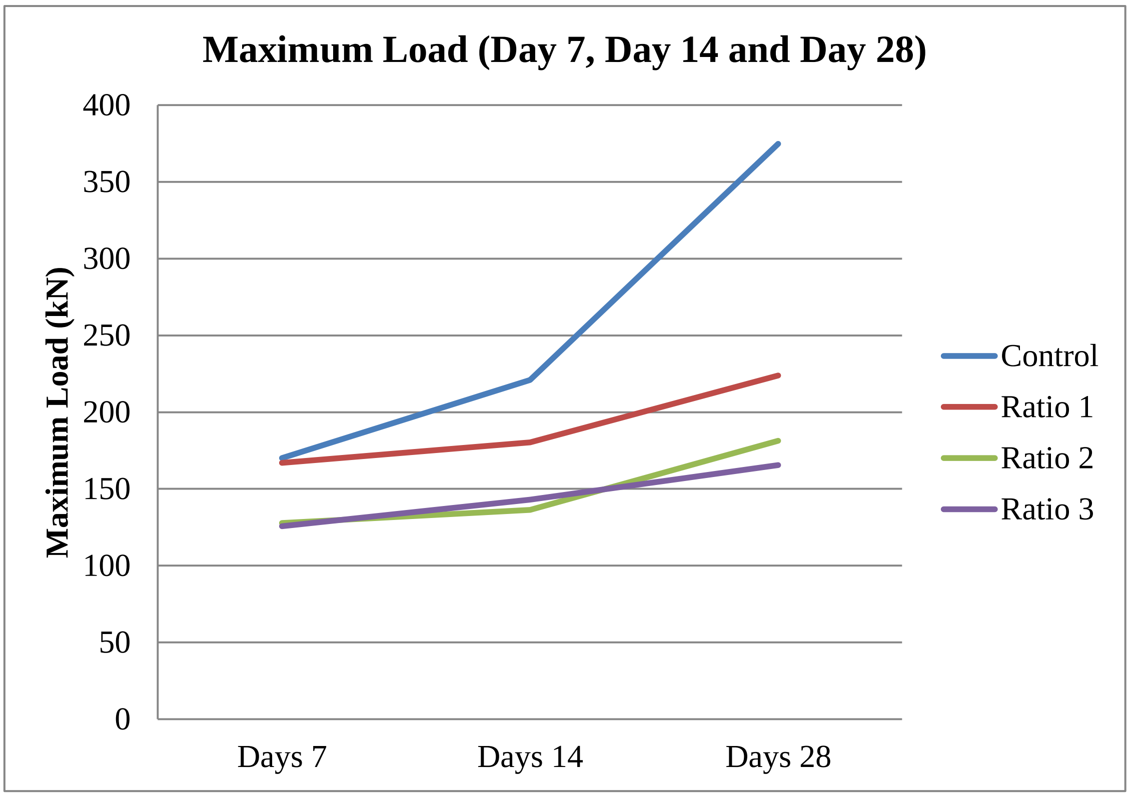

Figure 4.8: Graph of maximum load for control, ratio 1, ratio 2 and ratio 3.

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Figure 4.8 above shows the maximum load for control, ratio 1, ratio 2 and ratio 3 that test on days 7, days 14 and days 28. As stated in the line graph, the highest point is by the control samples for days 7 which is 170.097 kN, while days 14, 220.860 kN and days 28, 374.774 kN. For ratio 1 which is slightly lower from control for days 7 which is 166.961 kN and more low than control for days 14 which is 180.373 kN while for days 28 is major different from control which is 223.955 kN. For ratio 2 and 3 which is can see the huge differences from control. For the days 7, ratio 2 achieved 127.840 kN while ratio 3 is 125.626 kN, for days 14 supposedly ratio 3 is much lower than ratio 2 but due to technical problems, results turns out that ratio 3 which is 143.026 kN that are higher than ratio 2 which is 136.404 kN but still lower than the control which is 220.860 kN. On days 28, the value achieved by the samples from ratio 2 is much higher than ratio 3 which is 181.404 kN and 165.453 kN respectively but still lower when compared to control which is 374.774kN. It can be conclude that the factors that may affect the value of maximum load achieved are the percentages of polystyrene beads in the concrete. The higher the percentages of polystyrene beads in the concrete, the lower the maximum load can be applied on the concrete. This is because the purpose of the polystyrene beads is to reduce the weight of the concrete but the presence of it will make the concrete lose the strength. The strength of the concrete can be increase with the use of polystyrene beads by adding the admixtures in the concrete such as plasticizer and etc. Besides that, the factor that may affect the maximum load on the concrete is the days of curing. The higher the period of curing process, the more strength the concrete will gained. This is because the presence of water makes the hydration process occurs which is the releasing of chemical reaction in concrete cast. Adding water to portland cement starts a chemical reaction called hydration. As hydration proceeds over time, the portland cement and water are transformed into beneficial calcium silicate hydrate compounds. These compounds are the glue that holds the polystyrene beads together, creating the hard, solid material that known as concrete. There are other compounds that also form during the hydration process, but they are not responsible for strength. Practically speaking, curing is simply the process of keeping the hardened concrete moist so that it can continue to gain strength.

Table 4.9: Maximum strength for 7-days, 14-days and 28-days

	Days 7	Days 14	Days 28
Control	17.010	22.086	37.478
Ratio 1	16.695	18.037	22.395
Ratio 2	12.784	13.595	18.141
Ratio 3	12.562	14.319	16.545

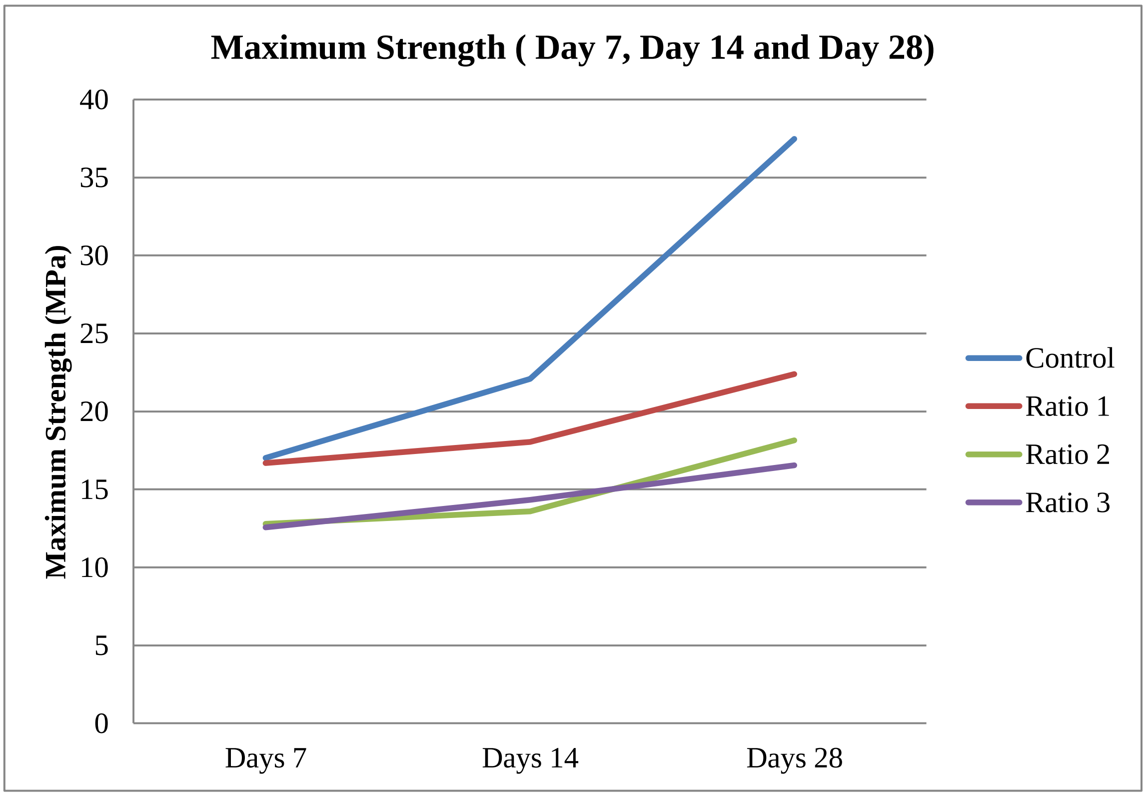

Figure 4.9: Graph of maximum strength for control, ratio 1, ratio 2 and ratio 3.

Figure 4.9 above shows the maximum strength for compressive strength test on days 7, days 14 and days 28 for control, ratio 1, ratio 2 and ratio 3 samples. As stated in the line graph, the highest value is by the control samples for days 7 which is 17.010 MPa, while days 14, 22.086 MPa and days 28, 37.478 MPa. Control acts as reference in this study for comparison between ratio 1, ratio 2 and ratio 3 because the control sample contains 0% of polystyrene beads. For ratio 1 which is slightly lower from control for days 7 which is 16.695 MPa as its samples contains only 12.5% of polystyrene beads while for ratio 2 which is more lower than control as its contains 25% of polystyrene beads in the concrete achieved maximum strength, 12.784 MPa and lowest value achieved is 12.562 MPa which is by ratio 3 as its samples contains the highest percent of polystyrene beads which is 37.5% in the concrete sample achieved. For days 14, maximum strength achieved by ratio 1 is slightly lower than a control which is 18.037 MPa and for ratio 2 is 13.595 MPa which are not as expected results due to the value is much lower than ratio 3 which is 14.319 Mpa. There are many factors that can give effect to the results such as the cube is not place correctly in the machine before conducting the test. Besides that, it could be during weighing the polystyrenes, the value is not accurate because of the polystyrene is light in weight and it may affect the percentage of polystyrene beads inside the concrete from the actual calculation. For 28 days, ratio 1 achieved the maximum strength of compressive strength about 22.395 MPa while for ratio 2 is 18.141 MPa and ratio 3 is 16.545 MPa which are the lowest maximum strength achieved compared to ratio 1, ratio 2 and control. It can be concluded that many factors can give effect to the value of maximum strength achieved such as the percentage of polystyrene beads in the concrete sample. The higher the percentages of polystyrene beads in the concrete, the lower the maximum strength of concrete which means the lower the maximum load can be applied to the concrete. This means the structure of the lightweight concrete cannot withstand huge load or it will failed or collapsed. Furthermore, polystyrene is known as it lightweight and low density but the presence of it in the concrete without aggregate or other admixtures will low the strength of concrete. Besides that, the factor that may affect the maximum load on the concrete is the days of curing. The higher the period of curing process, the more strength the concrete will gained. This is because the presence of water makes the hydration process occurs which is the releasing of chemical reaction in concrete cast. Adding water to portland cement starts a chemical reaction called hydration. As hydration proceeds over time, the portland cement and water are transformed into beneficial calcium silicate hydrate compounds. These compounds are the glue that holds the polystyrene beads together, creating the hard, solid material that known as concrete. There are other compounds that also form during the hydration process, but they are not responsible for strength. Practically speaking, curing is simply the process of keeping the hardened concrete moist so that it can continue to gain strength.

4.3 Flexural Test

Flexural strength is carried out to determine the tensile strength of concrete. It is measure of an unreinforced concrete beam to resist failure in bending. This test is carried out according to ASTM C78-02 by using (150x150x750) mm prism specimens. The prisms were subjected to four point load. About 24 beam sample is prepared for flexural test. Each ratio has 3 samples and takes the average results. The size of the beam sample is 150mm x150mm x750mm. The samples are curing using a gunny sack for 14 days and 28 days for each ratio. The test is conducted in the concrete laboratory, UMP.

Table 4.10: Maximum strength at 14-days

	Max. Load (kN)	Max Strength (MPa)	Time (s)	Weight (kg)
Control	25.27	3.369	24	35.27
Ratio 1	21.71	2.895	28	22.65
Ratio 2	20.42	2.723	26	29.57
Ratio 3	17.33	2.310	18	26.38

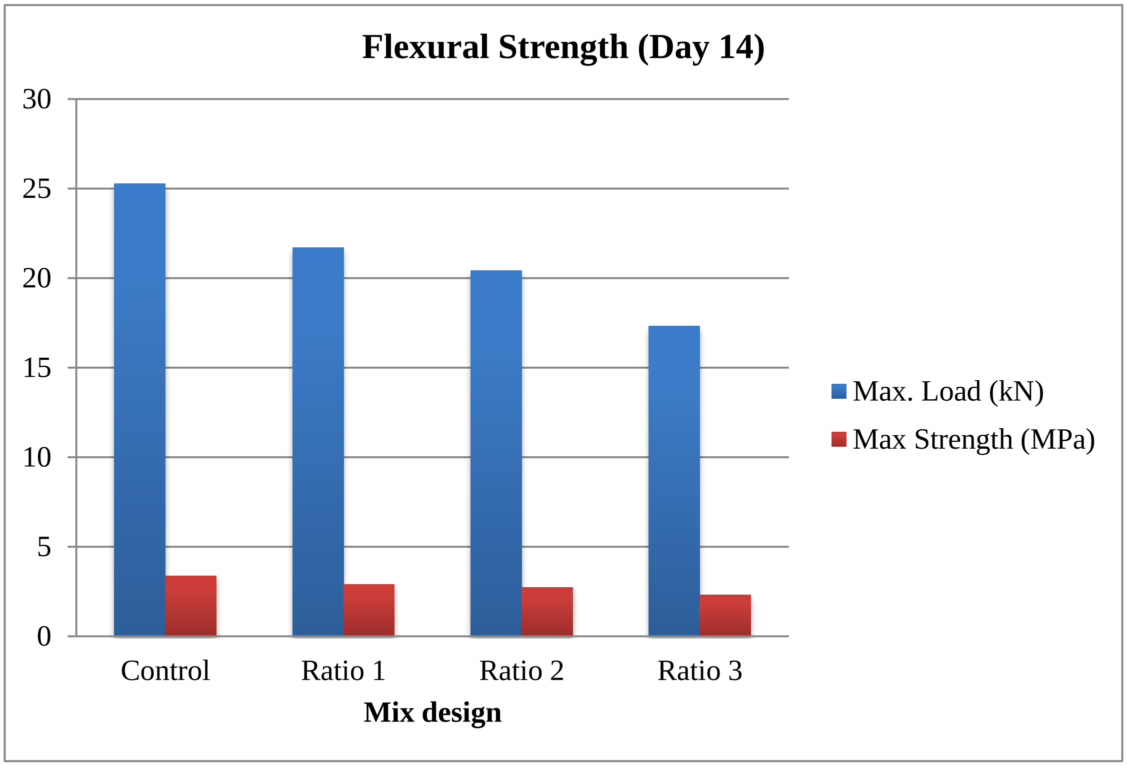

Figure 4.10: Graph of maximum strength and maximum load for beam flexural test.

The bar chart above shows the comparison between sample from control, ratio 1, ratio 2 and ratio 3 for days 14 undergo a flexural testing. As a reference sample in this study, the control sample gives the highest value for maximum load and also maximum strength which is 25.27 kN and 3.369 MPa respectively. Due to the sample contain 0% of polystyrene beads it should be the highest. For ratio 1, the maximum load is 21.71 kN and it maximum strength is 2.895 MPa. As for ratio 1 which contains 12.5% of polystyrene beads, both the value for maximum loads and maximum strength should be lower than the control sample. For ratio 2 which contains 25% polystyrene beads in the concrete achieved 20.42 kN which are slightly lower than the ratio 1 and lower than the control and for the maximum strength is 2.723 MPa that are also lower than the control and ratio 1. While for ratio 3, the maximum load is 17.33 kN and for the maximum strength is 2.310 MPa. It gives the lowest value of maximum load and maximum strength as the ratio contains the highest percentage of polystyrene beads which is 37.5%. Overall, the patterns of actual results are still following as expected results which are the maximum load and maximum strength should decreasing as the percentage of polystyrene beads is increasing.

Table 4.11: Maximum strength for 28-days

	Max. Load (kN)	Max Strength (MPa)	Time (s)	Weight (kg)
Control	28.9	3.466	25	35.05
Ratio 1	24.26	3.234	17	22.68
Ratio 2	13.66	1.821	19	28.08
Ratio 3	17.69	3.144	17	27.23

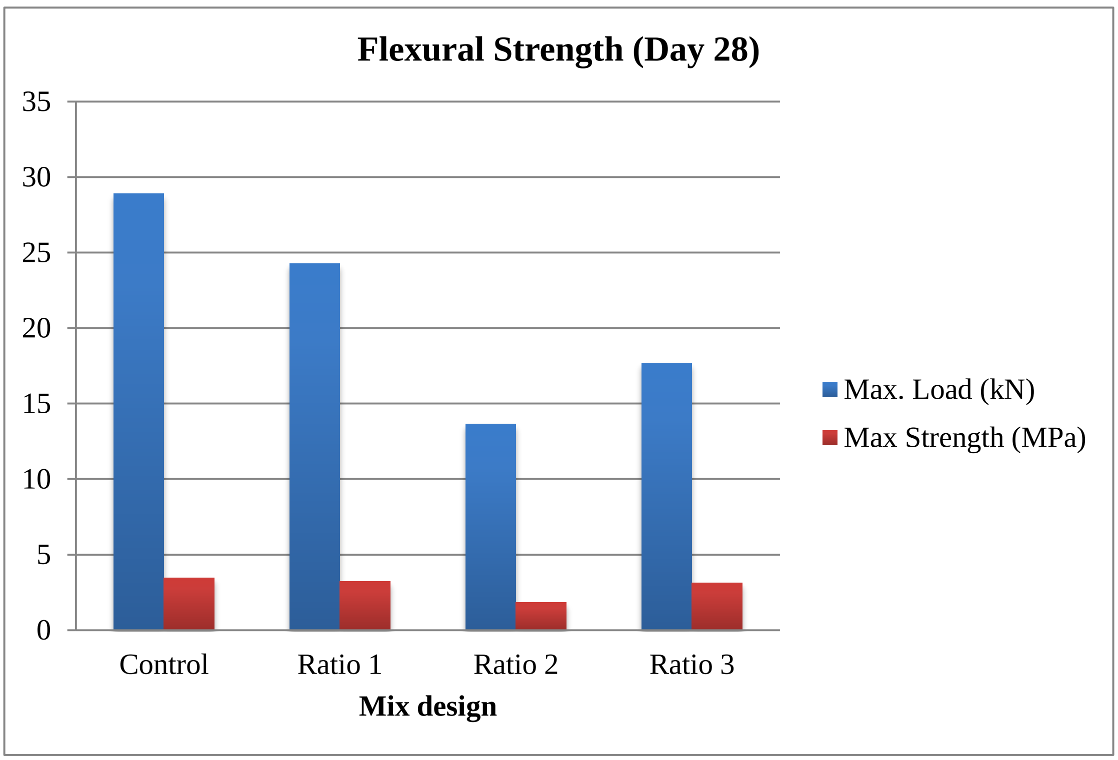

Figure 4.11: Graph of maximum strength and maximum load for beam flexural test.

Figure 4.11 above shows the comparison between sample from control, ratio 1, ratio 2 and ratio 3 for days 28 undergo a flexural testing. Control sample acts as reference because to the sample contain 0% of polystyrene beads thus it should get the highest value of maximum load and maximum strength from ratio 1, ratio 2 and ratio 3. The maximum load is 28.9 kN while maximum strength is 3.466 MPa. For ratio 1, the maximum load is 24.26 kN and it maximum strength is 3.234 MPa. The value is slightly lower than the control because the presence of polystyrene beads in the mixture. For ratio 3, the maximum load which is 17.69 and slightly lower than the ratio 1 and lower than control because it contains higher percentage of polystyrene beads but the value achieved is slightly higher than the maximum load achieved by ratio 2 which is 13.66 kN. While the maximum strength is 3.144 MPa also lower than the ratio 1 and control but higher than the maximum strength of ratio 2 which is 1.821 MPa. Overall, the lowest value of maximum load and maximum strength achieved for days 28 is by sample from ratio 2. It should be ratio 3 that will get the lowest value but due to few factors, ratio 2 achieved the lowest maximum load and maximum strength. Overall results are not follow the expected pattern of results which is decreasing as the percentage of polystyrene beads is increasing.

Table 4.12: Maximum strength at 14-days and 28-days for control

	Max. Load (kN)	Max Strength (MPa)
Days 14	25.27	3.369
Days 28	28.90	3.466

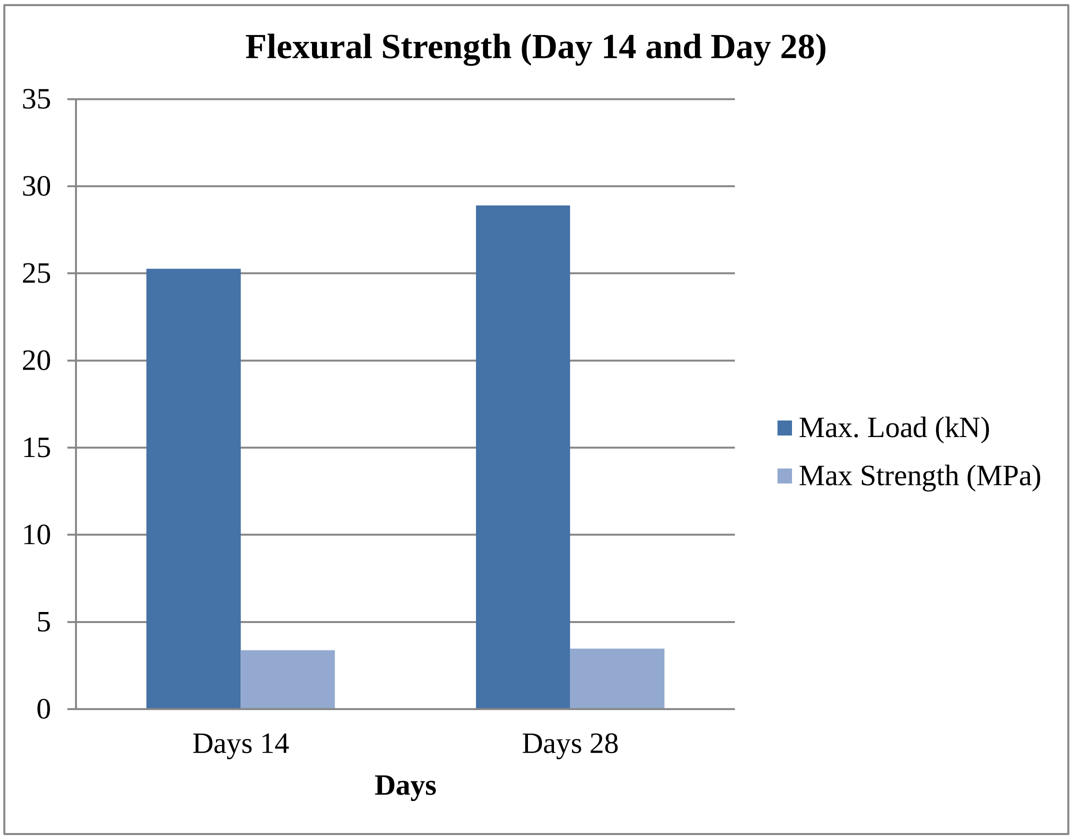

Figure 4.12: Graph of maximum load and maximum strength for flexural test for control.

The bar chart above shows the comparison between sample from control for days 14 and days 28 undergo a flexural testing. Control sample acts as reference because to the sample contain 0% of polystyrene beads. For days 14 the maximum load is 25.27 kN while maximum strength is 3.369 MPa. While for days 28 are higher than days 14 which are the maximum load are 28.90 kN and it maximum strength is 3.466 MPa. The values are increasing as period of curing increasing. This is because the longer the period for curing process take place, the more strength the sample will gained. For overall results are following the expected pattern of results which is increasing as the percentage of polystyrene beads are constant for this sample which is 0%

Table 4.13: Maximum strength for 14-days and 28-days for ratio 1

	Max. Load (kN)	Max Strength (MPa)
Days 14	21.71	2.895
Days 28	24.26	3.234

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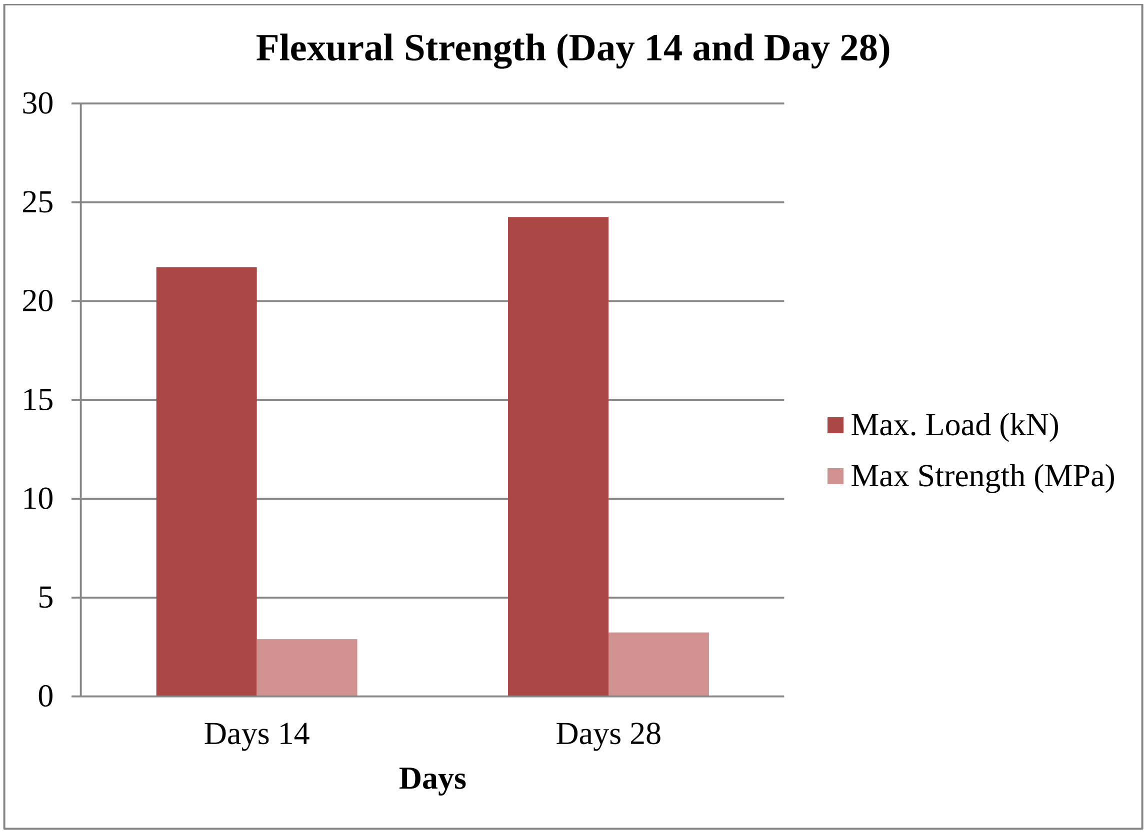

Figure 4.13: Graph of maximum load and maximum strength for flexural test for ratio 1.

The bar chart above shows the comparison between sample from ratio 1 for days 14 and days 28 undergo a flexural testing. Ratio 1 sample consists of the lowest percentage of polystyrene beads compare to ratio 2 and ratio 3 which is 12.5%. But still the strength of flexural and maximum load applied to it will still be lower than the control for days 14 and days 28. For days 14 the maximum load is 21.71 kN while maximum strength is 2.895 MPa. While for days 28 are higher than days 14 which are the maximum load are 24.26 kN and it maximum strength is 3.234 MPa. The values are increasing as period of curing increasing. Curing is the maintaining of acceptable moisture content and temperature in concrete during its early stage so that desired properties may develop. The strength and durability of concrete will be fully developed only if it is cured. This is because the longer the period for curing process take place, the more strength the sample will gained. For overall results are following the expected pattern of results which is increasing as the days of curing increasing and the percentage of polystyrene beads remain constant.

Table 4.14: Maximum strength at 14-days and 28-days for ratio 2

	Max. Load (kN)	Max Strength (MPa)
Days 14	20.42	2.723
Days 28	13.66	1.821

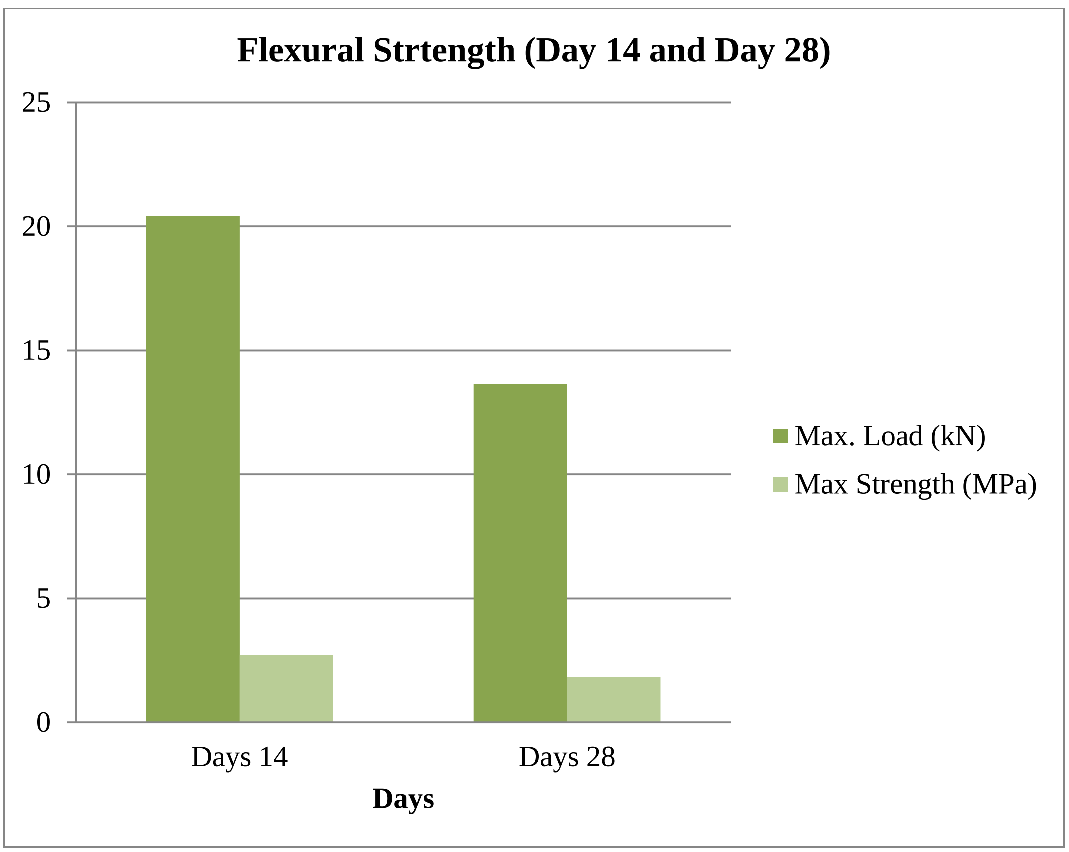

Figure 4.14: Graph of maximum load and maximum strength for flexural test for ratio 2.

The bar chart above shows the comparison between sample from ratio 2 for days 14 and days 28 undergo a flexural testing. Ratio 2 samples consists of the percentage of polystyrene beads which is 25% and the strength of flexural and maximum load applied to it will still be lower than the control for days 14 and days 28. For days 14 the maximum load is 20.42 kN while maximum strength is 2.723 MPa. While for days 28 are lower than days 14 which are the maximum load are 13.66 kN and it maximum strength is 1.821 MPa. Supposedly, the values are increasing as period of curing increasing because the longer the sample is soaked in water or undergo curing process, the more strength they will gained. The strength of concrete will be fully developed only if it is cured. They are a few factors that may affected the results of the sample as its lower than the expected results such as mistaken when doing mix concrete. Other than that, could be error during weighing the materials. Besides that, might be the sample is not placing correctly on the machine before conducting the testing or maybe the machine not setting correctly. So these factors can affect the results of maximum load and maximum strength that the sample achieved. For overall results are not following the expected pattern of results which is decreasing as the days of curing increasing although the percentage of polystyrene beads remain constant.

Table 4.15: Maximum strength at 14-days and 28-days for ratio 3

	Max. Load (kN)	Max Strength (MPa)
Days 14	17.33	2.310
Days 28	17.69	3.144

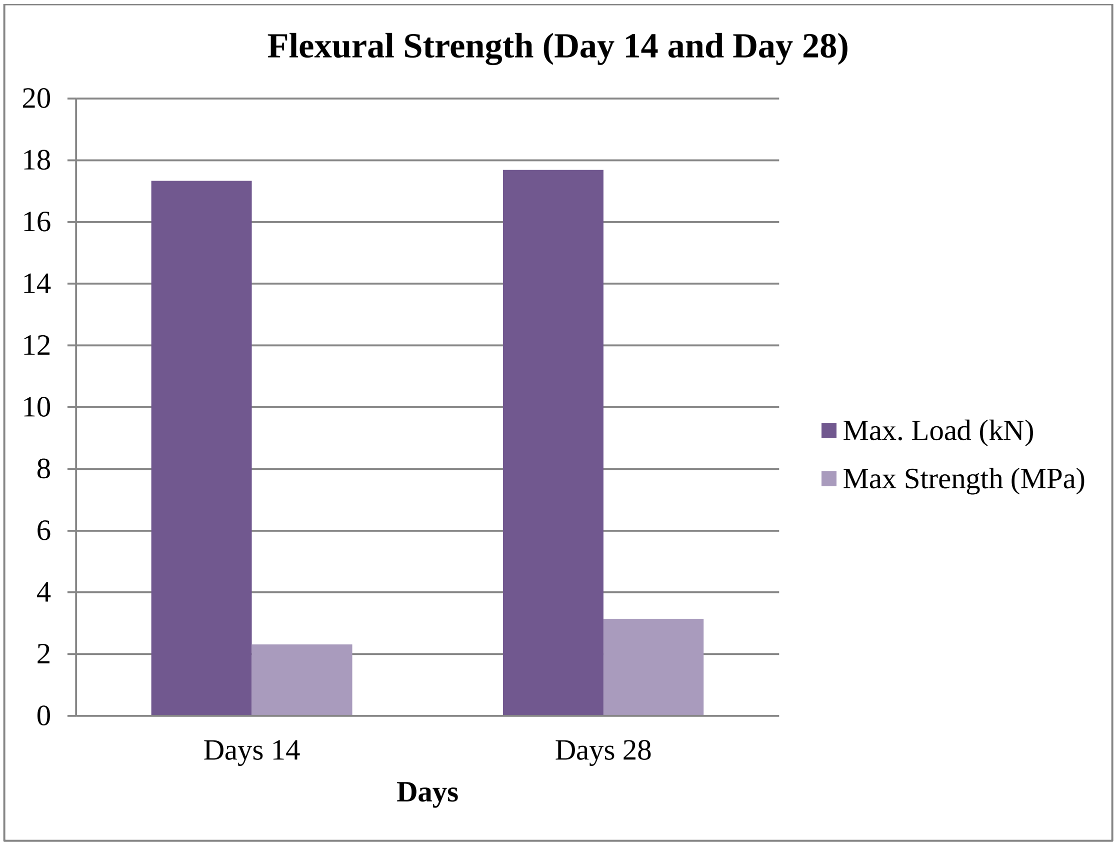

Figure 4.15: Graph of maximum load and maximum strength for flexural test ratio 3.

Figure 4.15 above shows the comparison between sample from ratio 3 for days 14 and days 28 undergo a flexural testing. Ratio 3 samples consist of the percentage of polystyrene beads which is 37.5% and the strength of flexural and maximum load applied to it are supposedly to be lower than the control for days 14 and days 28. For days 14 the maximum load is 17.33 kN while maximum strength is 2.310 MPa. While for days 28 are lower than days 14 which are the maximum load are 17.69 kN and it maximum strength is 3.144 MPa. The values are increasing as period of curing increasing because the longer the sample is undergo curing process, the more strength they will gained. The strength of concrete will be fully developed only if it is cured. Curing also ensures to maintain an adequate temperature of concrete in its early ages, as this directly affects the rate of hydration of cement and eventually the strength gain of concrete. For overall results are still following the expected pattern of results which is increasing as the days of curing increasing although the percentage of polystyrene beads remain constant.

Table 4.16: Maximum load at 14-days and 28-days

	Days 14	Days 28
Control	25.27	28.90
Ratio 1	21.71	24.26
Ratio 2	20.42	13.66
Ratio 3	17.33	17.69

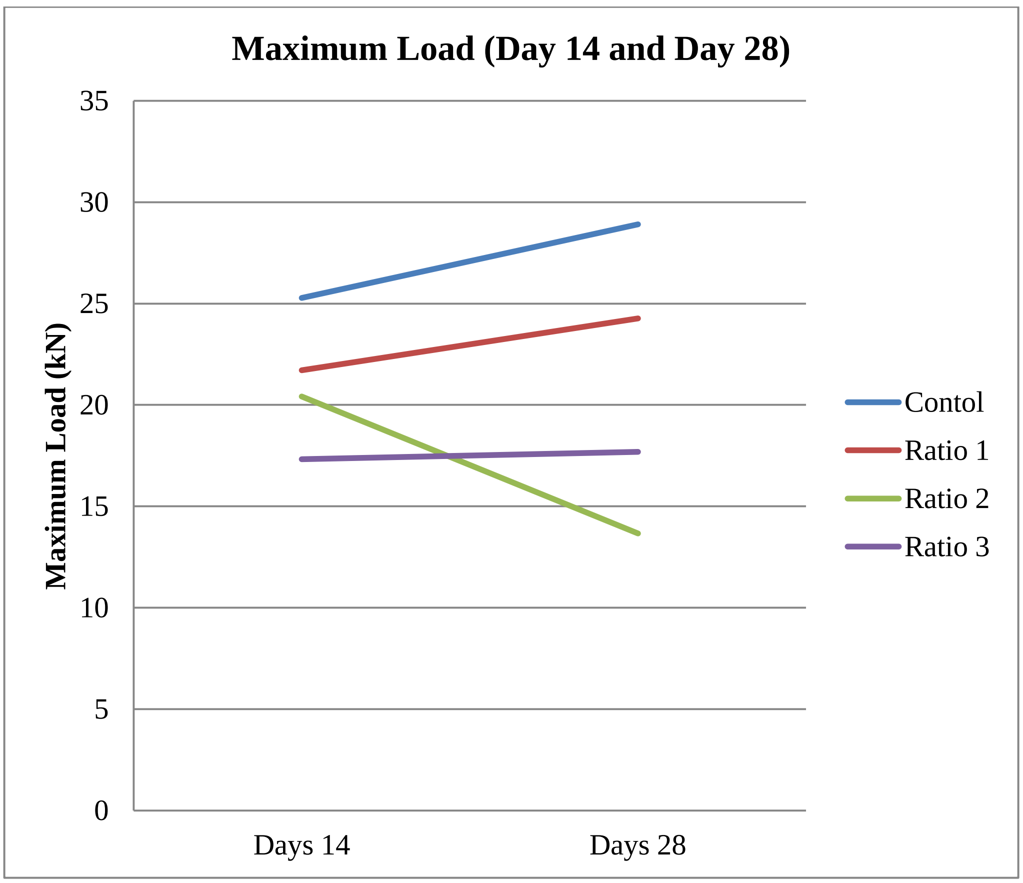

Figure 4.16: Graph of maximum load for flexural test.

Figure 4.16 above shows the graph line of maximum load for flexural test on days 14 and days 28 for control sample, ratio 1, ratio 2 and ratio 3. Maximum load is greatest load that a structure can bear without failing. From the graph, it is clearly stated that all the line is inclined upward from days 14 to days 28 for control sample, ratio 1 sample and also ratio 3 samples. But for ratio 2 the line is decline from days 14 to days 28. Supposedly, for ratio 2, the value of maximum load is higher than the ratio 3 on days 28. The value of maximum load achieved by the control samples on days 14 is 25.27 kN which are higher than the ratio 1 which is 21.71 kN and ratio 2 which is 20.42 kN and also ratio 3 which is 17.33 kN. While the maximum load achieved by control sample on days 28 is 28.90 Mpa which are higher than ratio 1 which is 24.26 MPa and also higher than ratio 3 which is 17.69 MPa but for a ratio 2, the value achieved is slightly different from the expected results which is lower than the ratio 3 and the value achieved by ratio 2 is 13.66 MPa. There are few factors that may affected the results of testing such as curing of concrete must begin as soon as possible after placement & finishing and must continue for a reasonable period of time as per the relevant standards, for the concrete to achieve its desired strength. Besides, protective measures to control moisture loss from the concrete surface are essential to prevent plastic shrinkage cracks. For this study, must make sure the gunny sack is wet properly and repeats the process for make sure the beam sample is not loss their moisture content. When to start the testing, the beam sample should not be dry out for a long time because it also can affect the strength of the beam. Besides that, the factor that influences the results are the percentage of polystyrene beads. As can see from the graph the highest maximum load is by control sample which are contain 0% polystyrene beads while for the others sample which contain at least 12% and highest percentage are 37.5% are much lower than the control sample. As the presence of polystyrene beads without aggregate and others additive chemical makes the concrete lose the strength although it has the same curing period with control sample. In a nut shell, the overall results are still following as the expected results exceptional for the ratio 2 on days 28.

Table 4.17: Maximum strength at 14-days and 28-days

	Days 14	Days 28
Control	3.369	3.466
Ratio 1	2.895	3.234
Ratio 2	2.723	1.821
Ratio 3	2.310	3.144

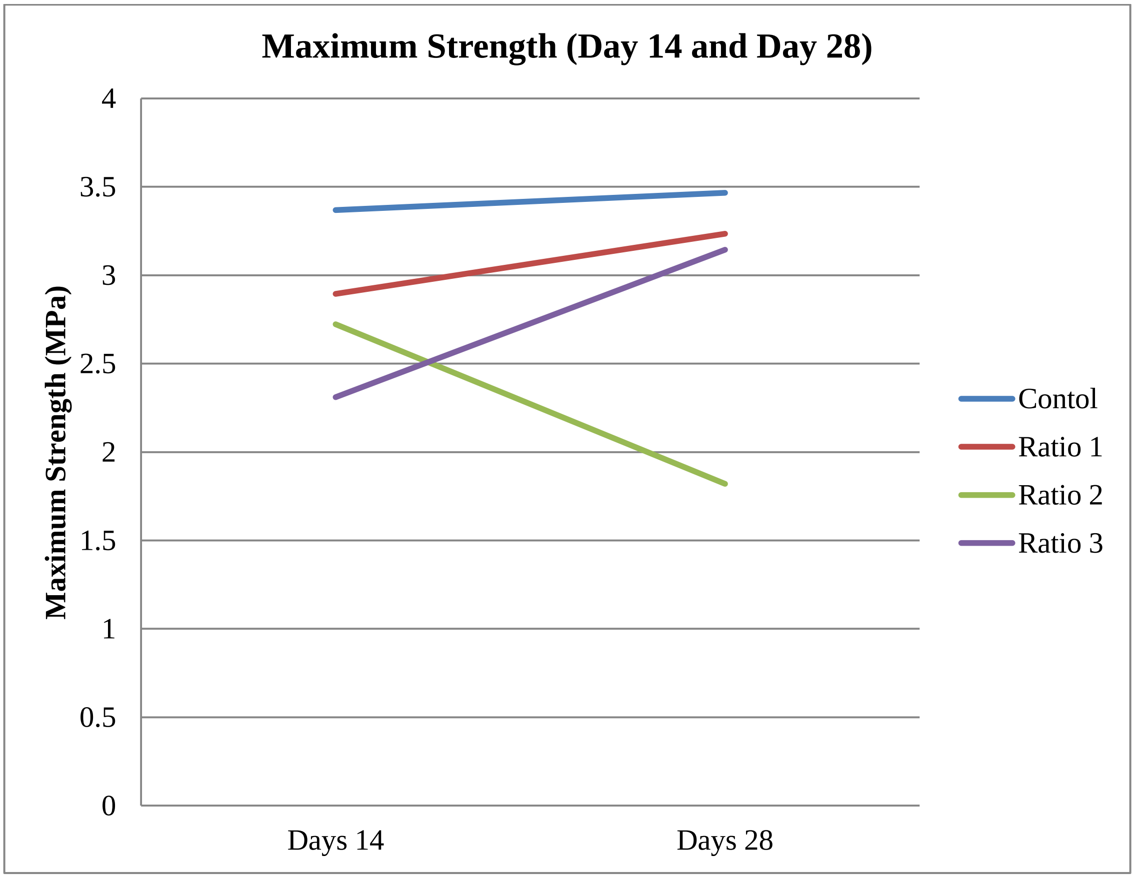

Figure 4.17: Graph of maximum strength for flexural test.

Figure 4.17 above shows the line graph about the maximum strength for flexural test on days 14 and days 28 for all 24 beam samples from control, ratio 1, ratio 2 and ratio 3. Maximum flexural strength is defined as the stress in a material just before it yields in a flexure test. From the graph, it is clearly stated that the all the line is inclined upward from days 14 to days 28 for control sample, ratio 1 sample and also ratio 3 samples. But for ratio 2 the line is decline from days 14 to days 28. Supposedly, for ratio 2, the value of maximum load is higher than the ratio 3 on days 28. The maximum flexural strength on days 14 by control sample is 3.369 kN while for days 28 is 3.466 kN. Control sample acts as a reference sample because the control sample contains 0% of polystyrene beads. For ratio 1 that contains the least percentage of polystyrene beads which is 12 % started to decrease when compared to control but increasing as the days increasing. The maximum value of flexural strength achieved by the ratio 1 for days 14 is 2.895 kN and for days 28 is 3.234 MPa. While for ratio 2, the graph is decreasing although the days are increasing. For days 28 the results achieved the lowest strength which is 1.821 MPa. This means it quiet far from the control. For days 14 the results is still following the pattern of expected results and still higher than the ratio 3 which is the value of maximum strength achieved is 2.723 MPa. In this study, ratio 3 contains the highest percentage of polystyrene beads which is 37.5%. On days 14, ratio 3 achieved the lowest flexural strength when compared to others which is 2.310 MPa. But for days 28 the strength achieved much higher than ratio 2 which is 3.144 MPa while ratio 2 is 1.821 MPa. They are many factors that affected the reading of the results such as technical error. This means, the machine is not set up properly before conducting the test. Besides that, the beam is dry out for too long and it lose it moisture thus make it lose its strength. So, it is better to conduct the test as soon as possible. Curing process also has important role in order to make the concrete achieved desired strength before testing. Curing of concrete plays a major role in developing the microstructure and pore structure of concrete. Curing of concrete means maintaining the moisture inside the concrete during the early ages and beyond in order to develop the desired properties in terms of strength. A good curing practice involves keeping the concrete damp until the concrete is strong enough to do its job. However, good curing practices are not always religiously followed in most of the cases, leading to a weak concrete. As can see from the graph the higher the percentage of polystyrene beads, the lower the value of maximum strength the concrete will achieved. In a nut shell, the overall results are still following as the expected results exceptional for the ratio 2 on days 28.

4.4 Conclusion of Results

Overall, for compressive strength, ratio 1 shows the most consistent increasing strength throughout the experiment from days 7, days 14 and also days 28 which is 16.695 N/mm^2, 18.037 N/mm^2 and 22.395 N/mm^2 respectively for maximum compressive strength. The graph also has consistent increasing for flexural test at days 14 and days 28 which is 2.895 N/mm^2 and 3.234 N/mm^2 respectively. The maximum compressive strength also fulfills strength of lightweight concrete for structural applications which is greater than 17 N/mm^2 and the strength that achieved in this test at 28 is 22.395 N/mm^2. Lastly, it can be said that the ratio 1 is optimum ratio for lightweight concrete compare to ratio 2 and ratio 3. For flexural strength at 28 days, this study gives the strength of 3.466 N/mm^2 for control, 3.234 N/mm^2 for ratio 1, 1.821 N/mm^2 for ratio 2 and 3.144 N/mm^2 for ratio 3. In this study, journal from Lect, Manolia Abed Al-wahab Ali acts as a reference and results from the journal for flexural strength at 28 days are 3.85 N/mm^2 for control, 3.12 N/mm^2 for ratio 1, 2.50 N/mm^2 for ratio 2 and 1.80 N/mm^2 for ratio 3. As a conclusion, it can be said that this experimental results are not within the results and the results from this study are slightly lower from the reference study.

4.5 Pattern of Failure for Flexural Test

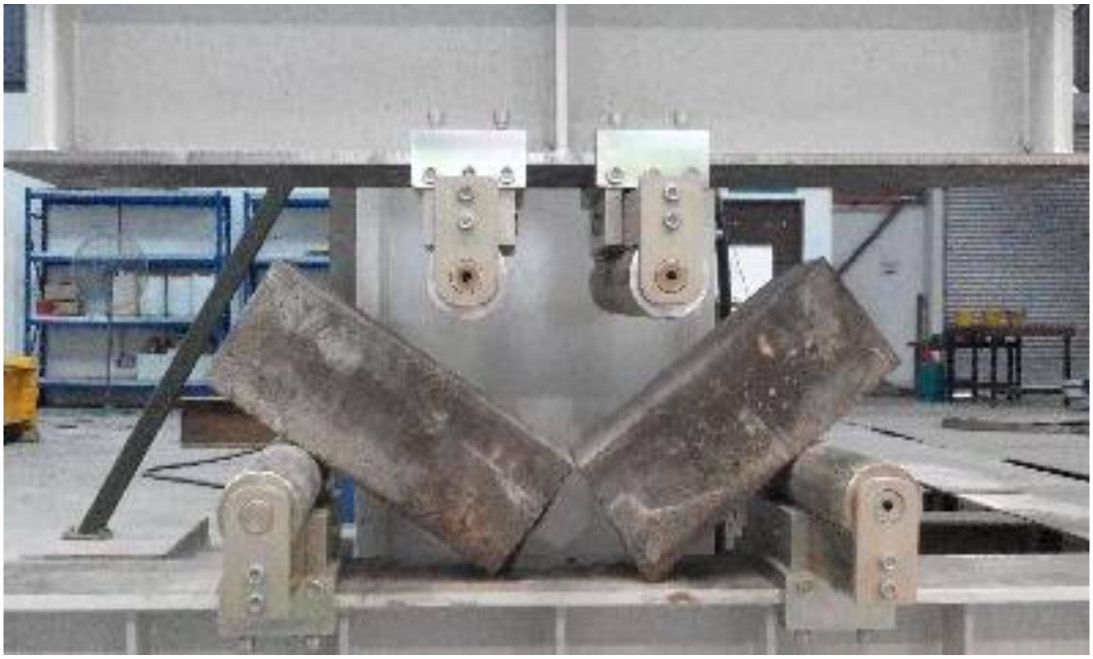

Figure 4.18: Patten of failure at 14-days for control sample

Figure 4.19: Patten of failure of beam on days 28 for control sample

Figure 4.20: Patten of failure of beam on days 14 for ratio 1 sample

Figure 4.21: Patten of failure of beam on days 28 for ratio 1 sample

Figure 4.22: Patten of failure of beam on days 14 for ratio 2 sample

Figure 4.23: Patten of failure of beam on days 28 for ratio 2 sample

Figure 4.24: Patten of failure of beam on days 14 for ratio 3 sample

Figure 4.25: Patten of failure of beam on days 28 for ratio 3 sample

4.6 Percentage of Polystyrene Beads in Concrete

Figure 4.26: 0% of polystyrene beads in concrete for control

Figure 4.27: 12% of polystyrene beads in concrete for ratio 1

Figure 4.28: 25% of polystyrene beads in concrete for ratio 2

Figure 4.29: 37.5% of polystyrene beads in concrete for ratio 3

CHAPTER 5

CONCLUSION

5.1 Introduction

The main objective of this study is to determine the flexural strength of lightweight concrete using polystyrene beads as partial replacement of sand with varies of design. The variables of mix proportions which are using different percentage of polystyrene beads as partial replacement of sand with weight of sand were used to obtain the flexural strength. Normal concrete were used for control sample to compare LWC with different percentage of polystyrene beads as partial sand replacement namely 12%, 25% and 37.5%. Different ages of curing in LWC which are 14 days and 28 days. An analysis of the data was conducted to obtain the flexural strength towards achieving the objective of this study.

5.2 Conclusion

According to the results and discussion in chapter 4, the following conclusion are drawn from study on compressive strength and flexural strength of lightweight concrete (LWC) using different percentage of polystyrene beads as partial sand replacement by total weight of sand. The results of experimental indicated that the percentage of polystyrene beads is an important role following by ages of curing for the tested specimens. The different percentages of polystyrene beads and ages of curing were given different effect to characteristics of LWC.

The conclusions that can be derived from the study are:

i. It is obviously shown that decreasing the percentage of polystyrene beads as sand replacement in lightweight concrete would increase the flexural strength of LWC-Polystyrene beads. It is indicated that, LWC-Polystyrene beads with 12% of polystyrene beads gradually increase the strength compared to others mixes.

ii. The effect of using 12% polystyrene beads in LWC-Polystyrene beads is more dominant in order to produce highest strength rather than that 25% and 37.5%. It is concluded that, LWC with 12% polystyrene beads mix can bond well.

iii. The compressive strength of 12% LWC-Polystyrene beads specimen increased gradually compared to those LWC specimens. The results shown that, LWC-Polystyrene with 12% of polystyrene beads significantly increase the strength of the LWC compared to other mixes.

iv. It also noted that, the increasing of curing days gradually effect the strength subjected to compressive strength and flexural strength. Thus, the LWC can achieve maximum strength at later ages of curing.

v. At the end of the experimental, it is appeared that the optimum mix design of LWC-Polystyrene beads by using 12% of polystyrene beads as partial sand replacement. The uses of polystyrene beads as partial sand replacement in LWC did not only improve the compressive strength but also flexural strength.

vi. It can be said that the results from this study are not within and slightly lower compare to the results from Lect. Manolia Abed Al-wahab Ali. This shows that the objective not achievable.

5.3 Recommendations

Overall, the application of polystyrene beads as sand replacement is suitable in lightweight concrete mix design. This material has a potential to use in the construction industry in future. The study need to be done more to improve the characteristics of the material. Some recommendations are done to improve the material:

i. A series of investigation on the effect of the lightweight concrete with polystyrene beads using admixtures such as plasticizer and silica fume.

ii. A series of investigation using reinforcement bar

iii. A series of investigations on modulus of elasticity in bending, flexural strain should be conducted.

iv. A series of investigation on various curing conditions should be considered

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APPENDIX A

Calculation for sample preparation

Total beam sample required:

Item	Ratio (Cement : Sand : EPS)	Water ratio	Nos.
Control	1 : 3 : 0	0.450	6
Ratio 1	1 : 2.5 : 0.5	0.325	6
Ratio 2	1 : 2 : 1	0.325	6
Ratio 3	1 : 1.5 : 1.5	0.325	6
Total sample required :			24

Volume for 1 sample = (0.15 x 0.15 x 0.75)
= 0.017 m^3

Volume for 24 sample = 0.017 x 24
= 0.408 m^3

Wastage 30% = 0.017 x 1.3
= 0.022 x 24 = 0.528

Material required in kg:

- For control (1 sample):

  Cement: 1 = 0.0055 x 1450 kg/m^3 = 8 kg

  Sand: 3 = 0.0165 x 1333 kg/m^3 = 22 kg

  EPS: 0 = 0

- For ratio 1 (1 sample):

  Cement: 1 = 0.0055 x 1450 kg/m^3 = 8 kg

  Sand: 2.5 = 0.0138 x 1333 kg/m^3 = 18.4 kg

  EPS: 0.5 = 0.0028 x 9.6 kg/m^3 = 0.03 kg

- For ratio 2 (1 sample):

  Cement: 1 = 0.0055 x 1450 kg/m^3 = 8 kg

  Sand: 2 = 0.011 x 1333 kg/m^3 = 14.7 kg

  EPS: 1 = 0.0055 x 9.6 kg/m^3 = 0.05 kg

- For ratio 3 (1 sample):

  Cement: 1 = 0.0055 x 1450 kg/m^3 = 8 kg

  Sand: 1.5 = 0.00825 x 1333 kg/m^3 = 11 kg

  EPS: 1.5 = 0.00825 x 9.6 kg/m^3 = 0.08 kg

Materials required for 24 beams (for 14 and 28 days):

Item	Nos.	Kg used			
		Cement	Sand	EPS	W/C
Control	8	63.80	175.80	-	28.71
Ratio 1	8	63.80	147.20	0.22	20.74
Ratio 2	8	63.80	117.30	0.42	20.74
Ratio 3	8	63.80	87.98	0.63	20.74