STUDY OF LIGHTWEIGHT CONCRETE BEHAVIOUR

Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as nailbility and lessened the dead weight. It is lighter than the conventional concrete. The use of lightweight concrete has been widely spread across countries such as USA, United Kingdom and Sweden.

The main specialties of lightweight concrete are its low density and thermal conductivity. Its advantages are that there is a reduction of dead load, faster building rates in construction and lower haulage and handling costs.

Lightweight concrete maintains its large voids and not forming laitance layers or cement films when placed on the wall. This research was based on the performance of aerated lightweight concrete. However, sufficient water cement ratio is vital to produce adequate cohesion between cement and water. Insufficient water can cause lack of cohesion between particles, thus loss in strength of concrete. Likewise too much water can cause cement to run off aggreagate to form laitance layers, subsequently weakens in strength.

Therefore, this fundamental research report is prepared to show activities and progress of the lightweight concrete. Focused were on the performance of aerated lightweight concrete such as compressive strength tests, water absorption and density and supplementary tests and comparisons made with other types of lightweight concrete.

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KAJIAN TERHADAP KELAKUAN KONKRIT RINGAN

Konkrit ringan ditakrifkan sebagai konkrit yang dicampur demean agen 'pengembang' di mana pertambahan isipadu campuran berlaku dan memberi kualiti tambah bahan seperti pengikatan kuat dan ringan antara zarah-zarah simen dan batu baur. Konkrit ini adalah ringan dari konkrit biasa dan penggunaannya berleluasa di Negara-negara Amerika, United Kingdom and Sweden.

Ciri utama konkrit ringan ini ialah ketumpatan dan pengaliran haba yang rendah. Kebaikan bahan di mana pengurangan berat bahan amat ketara, justru pembinaan lebih mudah dan seterusnya pengurangan perbelanjaan dari segi pengangkutan untuk pembinaan.

Konkrit ringan mengekalkan liang dan tidak mengakibatkan pembentukan lapisan 'laitance' layers atau filem simen apabila di pasang di dinding. Penyelidikan ini berasaskan kelakuan konkrit ringan berliang udara. Walaubagaimanapun, nisbah air simen mencukupi penting untuk menghasilkan lekatan antara simen dan air yang baik. Kekurangan air boleh menyebabkan ikatan di antara zarah-zarah lemah, justru hilang kekuatan konkrit tersebut. Begitu juga sebaliknya, jika nisbah air tinggi akan menyebabkan simen tidak dapat mengikat batu-baur sepenuhnya untuk pembentukan lapisan 'laitance' seterusnya melemahkan kekuatan konkrit.

Oleh yang demikian, laporan penyelidikan asas ini hanya menunjukkan aktiviti dan progres dalam pembentukan konkrit ringan. Kelakuan konkrit ringan seperti kekuatan mampatan, penyerapan air, ketumpatan dan ujian tambahan telah dijalankan dan perbandingan telah dibuat dengan bahan binaan konkrit ringan lain.

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CHAPTER 1 : INTRODUCTION

1.0 PREFACE

Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as nailbility and lessened the dead weight.

Lightweight concrete maintains its large voids and not forming laitance layers or cement films when placed on the wall. This research was based on the performance of aerated lightweight concrete. However, sufficient water cement ratio is vital to produce adequate cohesion between cement and water. Insufficient water can cause lack of cohesion between particles, thus loss in strength of concrete. Likewise too much water can cause cement to run off aggreagate to form laitance layers, subsequently weakens in strength.

This research report is prepared to show the activities and progress of the lightweight concrete research project. The performance of aerated lightweight concrete such as compressive strength tests, water absorption and density and supplementary tests and comparisons made with other types of lightweight concrete were carried out.

1.1 Research activity

OPERATIONAL PLAN													
No.	TASK	YEAR 2002				YEAR 2003				YEAR 2004			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	LITERATURE REVIEW												
2	TAKING SAMPLES, PREPARATION (MANUFACTURE)												
3	TESTING AND DATA COLLECTION												

4	ANALYSIS	
5	PRODUCT FORMULATION	
6	REPORT WRITING	
	Technology transfer Activities:	
	Discussions with industries	
	Final Report	
* Task completed		
* Task not yet completed		
Q1	: First Quarter (Jan, Feb, Mac)	
	: Milestone not yet completed	
Technology Transfer Activities - post research activities, eg, exhibition, negotiation for commercialization		
PROJECT ACTIVITIES COMPLETED:		100%

2.0 LIETRATURE REVIEW OF THE LIGHTWEIGHT CONCRETE

2.1 Introduction

Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as nailibility and lessened the dead weight [1]. It is lighter than the conventional concrete with a dry density of 300 kg/m^3 up to 1840 kg/m^3; 87 to 23% lighter. It was first introduced by the Romans in the second century where 'The Pantheon' has been constructed using pumice, the most common type of aggregate used in that particular year [2]. From there on, the use of lightweight concrete has been widely spread across other countries such as USA, United Kingdom and Sweden.

The main specialties of lightweight concrete are its low density and thermal conductivity. Its advantages are that there is a reduction of dead load, faster building rates in construction and lower haulage and handling costs. The building of 'The Pantheon' of lightweight concrete material is still standing eminently in Rome until now for about 18 centuries as shown in Figure 1. it shows that the lighter materials can be used in concrete construction and has an economical advantage.

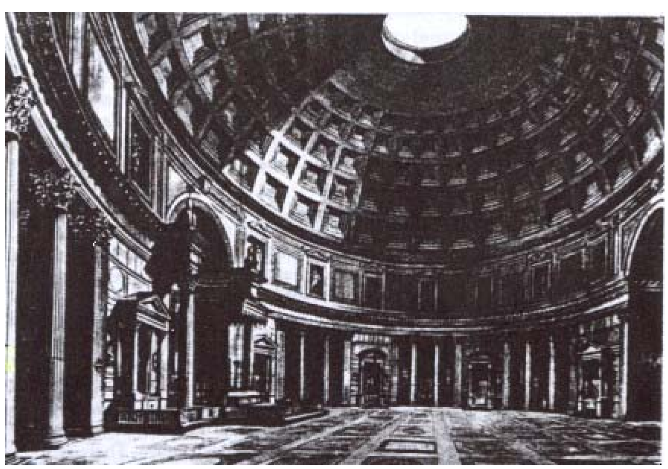

FIGURE 1: 'The Pantheon' [5]

2.2 TYPES OF LIGHTWEIGHT CONCRETE

Lightweight concrete can be prepared either by injecting air in its composition or it can be achieved by omitting the finer sizes of the aggregate or even replacing them by a hollow, cellular or porous aggregate. Particularly, lightweight concrete can be categorized into three groups:

i) No-fines concrete
ii) Lightweight aggregate concrete
iii) Aerated/Foamed concrete

2.2.1 NO-FINES CONCRETE

No-fines concrete can be defined as a lightweight concrete composed of cement and fine aggregate. Uniformly distributed voids are formed throughout its mass. The main characteristics of this type of lightweight concrete is it maintains its large voids and not forming laitance layers or cement film when placed on the wall. Figure 2 shows one example of No-fines concrete.

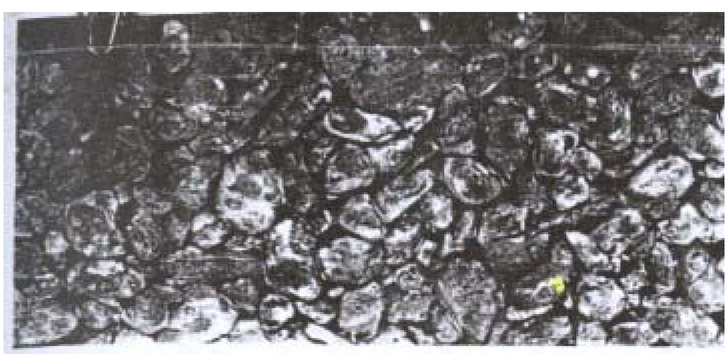

FIGURE 2: No-fines Concrete [2]

No-fines concrete usually used for both load bearing and non-load bearing for external walls and partitions. The strength of no-fines concrete increases as the cement content is increased. However, it is sensitive to the water composition. Insufficient water can cause lack of cohesion between the particles and therefore, subsequent loss in strength of the concrete. Likewise too much water can cause cement film to run off the aggregate to form laitance layers, leaving the bulk of the concrete deficient in cement and thus weakens the strength.

2.2.2 LIGHTWEIGHT AGGREGATE CONCRETE

Porous lightweight aggregate of low specific gravity is used in this lightweight concrete instead of ordinary concrete. The lightweight aggregate can be natural aggregate such as pumice, scoria and all of those of volcanic origin and the artificial aggregate such as expanded blast-furnace slag, vermiculite and clinker aggregate. The main characteristic of this lightweight aggregate is its high porosity which results in a low specific gravity [17].

The lightweight aggregate concrete can be divided into two types according to its application. One is partially compacted lightweight aggregate concrete and the other is the structural lightweight aggregate concrete. The partially compacted lightweight aggregate concrete is mainly used for two purposes that is for precast concrete blocks or panels and cast in-situ roofs and walls. The main requirement for this type of concrete is that it should have adequate strength and a low density to obtain the best thermal insulation and a low drying shrinkage to avoid cracking [2].

Structurally lightweight aggregate concrete is fully compacted similar to that of the normal reinforced concrete of dense aggregate. It can be used with steel reinforcement as to have a good bond between the steel and the concrete. The concrete should provide adequate protection against the corrosion of the steel. The shape and the texture of the aggregate particles and the coarse nature of the fine aggregate tend to produce harsh concrete mixes. Only the denser varieties of lightweight aggregate are suitable for use in structural concrete [2]. Figure 3 shows the feature of lightweight aggregate concrete.

FIGURE 3: Lightweight Aggregate Concrete [4]

2.2.3 AERATED CONCRETE

Aerated concrete does not contain coarse aggregate, and can be regarded as an aerated mortar. Typically, aerated concrete is made by introducing air or other gas into a cement slurry and fine sand. In commercial practice, the sand is replaced by pulverized-fuel ash or other siliceous material, and lime maybe used instead of cement [2].

There are two methods to prepare the aerated concrete. The first method is to inject the gas into the mixing during its plastic condition by means of a chemical reaction. The second method, air is introduced either by mixing-in stable foam or by whipping-in air, using an air-entraining agent. The first method is usually used in precast concrete factories where the precast units are subsequently autoclaved in order to produce concrete with a reasonable high strength and low drying shrinkage. The second method is mainly used for in-situ concrete, suitable for insulation roof screeds or pipe lagging. Figure 4 shows the aerated concrete.

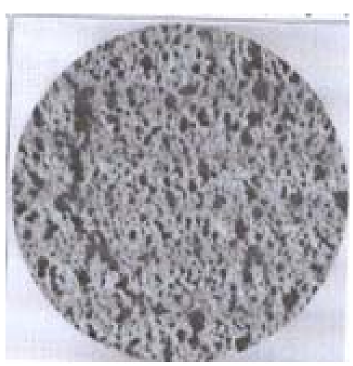

FIGURE 4: Aerated Concrete [3]

The differences between the types of lightweight concrete are very much related to its aggregate grading used in the mixes. Table 1 shows the types and grading of aggregate suitable for the different types of lightweight concrete [2].

Table 1: Types and Grading of Lightweight Concrete

Type Of Lightweight Concrete	**Type Of Aggregate**	**Grading of Aggregate (Range of Particle Size)**
No-fines concrete	Natural Aggregate Blast-furnace slag Clinker	Nominal single-sized material between 20mm and 10mm BS sieve
Partially compacted lightweight aggregate concrete	Clinker Foamed slag Expanded clay, shale, slate, vermiculite and perlite Sintered pulverized-fuel ash and pumice	May be of smaller nominal single sizes of combined coarse and fine (5mm and fines) material to produce a continues but harsh grading to make a porous concrete
Structural lightweight aggregate concrete	Foamed slag Expanded clay, shale or slate and sintered pulverized fuel ash	Continues grading from either 20mm or 14mm down to dust, with an increased fines content (5mm and fines) to produce a workable and dense concrete

Aerated concrete	Natural fine aggregate Fine lightweight aggregate Raw pulverized-fuel ash Ground slag and burnt shales	The aggregate are generally ground down to finer powder, passing a 75 µm BS sieves, but sometimes fine aggregate (5mm and fines) is also incorporated

2.3 ADVANTAGES AND DISADVANTAGES OF LIGHTWEIGHT CONCRETE

Table 2 shows the advantages and disadvantages of using lightweight concrete as structure [2].

Table 2: Advantages and Disadvantages of Lightweight Concrete

Advantages	Disadvantages
i) rapid and relatively simple construction ii) Economical in terms of transportation as well as reduction in manpower iii) Significant reduction of overall weight results in saving structural frames, footing or piles	i) Very sensitive with water content in the mixtures ii) Difficult to place and finish because of the porosity and angularity of the aggregate. In some mixes the cement mortar may separate the aggregate and float towards the surface

Advantages	**Disadvantages**
iv) Most of lightweight concrete have better nailing and sawing properties than heavier and stronger conventional concrete	iii) Mixing time is longer than conventional concrete to assure proper mixing

2.4 APPLICATION OF LIGHTWEIGHT CONCRETE

Lightweight concrete has been used since the eighteen centuries by the Romans. The application on the 'The Pantheon' where it uses *pumice* aggregate in the construction of cast in-situ concrete is the proof of its usage. In USA and England in the late nineteenth century, *clinker* was used in their construction for example the 'British Museum' and other low cost housing. The lightweight concrete was also used in construction during the First World War. The United States used mainly for shipbuilding and concrete blocks. The *foamed blast furnace-slag* and *pumice aggregate* for block making were introduced in England and Sweden around 1930s.

Nowadays with the advancement of technology, lightweight concrete expands its uses. For example, in the form of *perlite* with its outstanding insulating characteristics. It is widely used as loose-fill insulation in masonry construction where it enhances fire ratings, reduces noise transmission, does not rot and termite resistant. It is also used for vessels, roof decks and other applications. Figure 5 shows some examples of lightweight concrete used in different forms.

CHAPTER 3 : METHODOLOGY

3.1 TESTING PROGRAM OF LIGHTWEIGHT CONCRETE

In order to study the behavior of lightweight concrete, normal concrete testing was done to determine the material and structural properties of each type of lightweight concrete and how will these properties differ according to a different type of mixture and its composition.

Once concrete has hardened it can be subjected to a wide range of tests to prove its ability to perform as planned or to discover its characteristics. For new concrete this usually involves casting specimens from fresh concrete and testing them for various properties as the concrete matures.

3.2 COMPRESSIVE STRENGTH

Compressive strength is the primary physical property of concrete (others are generally defined from it), and is the one most used in design. It is one of the fundamental properties used for quality control for lightweight concrete. Compressive strength may be defined as the measured maximum resistance of a concrete specimen to axial loading. It is found by measuring the highest compression stress that a test cylinder or cube will support.

There are three type of test that can be use to determine compressive strength; cube, cylinder, or prism test. The ‘concrete cube test' is the most familiar test and is used as the standard method of measuring compressive strength for quality control purposes (Neville, 1994). Please refer appendix 1 for details.

3.3 WATER ABSORPTION

These properties are particularly important in concrete, as well as being important for durability. (J.H Bungey, 1996). It can be used to predict concrete durability to resist corrosion. Absorption capacity is a measure of the porosity of an aggregates; it is also used as a correlation factor in determination of free moisture by oven-drying method (G.E Troxell, 1956).

The absorption capacity is determined by finding the weight of surface-dry sample after it has been soaked for 24 hr and again finding the weight after the sample has been dried in an oven; the difference in weight, expressed as a percentage of the dry sample weight, is the absorption capacity (G.E Troxell, 1956).

Absorption capacity can be determine using BS absorption test. The test is intended as a durability quality control check and the specified age is 28-32 days (S.G Millard). Test procedure as been describe by BS 1881: Part 122 is as listed in the appendix 2.

3.4 DENSITY

The density of both fresh and hardened concrete is of interest to the parties involved for numerous reasons including its effect on durability, strength and resistance to permeability.

Hardened concrete density is determined either by simple dimensional checks, followed by weighing and calculation or by weight in air/water buoyancy methods (ELE International, 1993). To determine the density of lightweight concrete sample, the simple method is preferred as listed in the appendix 3.

CHAPTER 4 : RESULTS & DISCUSSION

4.1 INTRODUCTION

In this chapter, discussion will be focused on the performance of aerated lightweight concrete. All the tests method adopted were describe in the previous chapter. The results presented in this chapter are regarding the compressive strength test, density, moisture content, and water absorption for different trial mixes of the lightweight concrete.

4.2 STRENGTH AND DENSITY COMPARISON

The purpose of this test is to identify the performance of aerated lightweight concrete in term of density and compressive strength. The result are presented in Table 1 and illustrated in Figure 1. Based on Figure 1, it can be seen that compressive strength for aerated lightweight concrete are low for lower density mixture. The increment of voids throughout the sample caused by the foam in the mixture will lower the density. As a result, compressive strength will also decrease with the increment of those voids.

The required compressive strength of lightweight concrete is 3.45 MPa at 28 days as a non load bearing wall. The compressive strengths obtained from these mixtures carried out are higher than 3.45 MPa and therefore it is acceptable to be produced as non-load bearing structure.

However, the compressive strength for the mixture with density of 2050 kg/m^3 is slightly low compared with density of 2040 kg/m^3. This is due to the compaction problem during mixing process. The final mixture is quite dry and since compaction is not perfectly done, samples are not well compacted. This has resulted the compressive strength to be lower than the mixture with lower density.

4.3 COMPRESSIVE STRENGTH

As been discussed before, trial and error method was used in determining the most suitable mixture in preparing research samples. Fourteen (14) trial mixes have been prepared during the research and from the results, the mixture with the highest compressive strength with low density will be used for further investigation.

Compressive strength of aerated lightweight concrete is determined on the 7, 14, 21 and 28 days for each sample. There were three samples for each test and the results would be taken as the average of these three. Fewer variables had been set for different mixture, this variable would be changed accordingly while the others were fixed to forecast their effect on the mixture. Percentage of foam, foam agent and water, cement and sand ratio were the variables made during the mixing process. For example, three mixtures were prepared to determine the effect of different foam agent and water, cement and sand ratio. The percentage of foam applied is fixed for three mixtures and the difference in the results would occur because of the foam agent and water ratio. All the results were based on the 75% foam injected in the mixture.

Figure 2 shows the compressive strength of aerated lightweight concrete according to the percentage of foam in each mixture. It can be seen that the mixture with 25% of foam is higher than the compressive strength of 100% foam. This is because, with higher percentage of foam, voids throughout the sample will be increased, and as has been discussed ealier, this would result in the decrease of the compressive strength. Compressive strength of mixture with 50% foam is slightly higher than mixture with 75% foam.

The density of 25%, 50%, 75%, and 100% of foam is 2040 kg/m^3, 1820 kg/m^3, 1810 kg/m^3, and 1470 kg/m^3 respectively. The density of 50% and 75% of foam mixture is the same as been showed in Figure 2, compressive strength for this two mixture did not differ much. But it can be seen that there is a difference between 25% of foam mixture and 100% of foam mixture. The density of 25% of foam mixture is 27% higher as compared to 100% of foam mixture and seen in Table 2, the compressive strength is 85.4% higher at 28 days. For a 25% mixture the compressive strength is 17.27 MPa and for 100% mixture is 2.52 MPa. It is seen that the reduction in density or the addition of voids in concrete would effect on the strength of the concrete. The minimum compressive strength is 3.45 MPa of non-load bearing structure should be accomplish with the right proportion of foam.

The second variable set up is the foam agent and water ratio. According to Pan Pacific Engineering Pty Ltd, one liter of foam agent should be diluted with 40 liter of clean water and it makes the ratio of 1:40 but according to Alex Liew on his paper of work of Lightweight Concrete Method, LCM the ratio should be 1:30. Therefore, we have prepared three samples with foam agent and water ratio of 1:40, 1:30, and 1:25 to see the differences. The results were compared and tabulated Table 3 and Figure 3.0.

Based on Figure 3, it can be seen that, the foam agent and the water ratio of 1:40 gives the highest compressive strength followed by 1:30 and 1:25. Compressive strength at 28 days for 1:40, therefore it can be concluded that of the ratio between 1:30 and 1:40 can be applied to the foam agent and water. But as for the 1:25 ratio, the compressive strength is slightly lower to the previous two mixtures with compressive strength of 5.5 MPa. This is because, during the mixing process, it can be seen that the foam are not perfectly produced. It is not fully expanded as the other mixture with 1:40 and 1:30 ratio. 1:25 ratio should not be recommended for future preparation since that the water was insufficient to dilute the foam agent correctly.

The next variable is the cement sand ratio. To see the effect of cement sand ratio on the compressive strength, we have prepared three mixtureof different cement sand ratio of 1:2, 1:3, and 1:4 accordingly. The comparison between these different mixtures can be seen in Figure 4. It can be seen that mixture of 1:2 cement sand ratio gives the highest compressive strength. This is followed by 1:3 and 1:4 ratios.

According to Table 4, compressive strength at 28 days of mixture with 1:2 cement sand ratio is 22.99 MPa, for 1:3 is 13.12 MPa, and for 1:4 is 10.34 MPa. This shows that the compressive strength of mixture with 1:2 ratio is 42.9% higher than mixture with 1:3 ratio and the density is 12.15% higher. Though the compressive strength is slightly higher, but mixture of 1:2 ratios is not economic and is considered to be richer mix. Although the mixtures of 1:3 and 1:4 cement sand ratio gives lower compressive strength of 13.12 MPa and 10.34 MPa but it is sufficient for non-load bearing structure as well.

The last variable is the water cement ratio that has been set to get the most suitable and economic mixture. The three mixture were prepared with different water cement ratio of 1: 0.25, 1: 0.35, and 1: 0.45 to see the effect of this variable on aerated lightweight concrete behavior. The comparison between the compressive strength of these three mixtures is illustrated in Figure 5. It can be seen that mixture with water cement ratio of 1: 0.35 gives the highest compressive strength among the three mixtures.

Referring to Table 5, the compressive strength of mixture of 1: 0.35 water cement ratio is 16.73 MPa, 1 :0.45 is 13.12 MPa, and for 1: 0.25 its 12.18 MPa. It can be seen that despite higher compressive strength mixture with 1: 0.35, it has low density as well of 1920 kg/m^3 as compared to the mixture ratio of 1: 0.25 which has the density is 2040 kg/m^3. So, it can be concluded that the water cement ratio of 1: 0.35 is suitable for other mixture of aerated lightweight concrete.

4.4 WATER ABSORPTION

Water absorption is an important factor due to the porous structure of the aerated lightweight concrete. The water absorption test is done using the samples prepared at the age of 28 days using the method as been describe in methodology chapter. The purpose of this test is to identify the capability of the concrete to absorb water. There are three samples for each test and the average result will be taken.

Figure 6 shows different water absorption for different percentage of foam. It can be seen that, water absorption increased when the percentage of foam is increased. 100% of foam shows the highest water absorption followed by 75%, 50% and lastly 25% of foam. This is because the higher percentage of foam applied in each mixture, the total voids distributed in the samples will be increased. This will result higher water absorption capacity since sample are capable to absorb more water when more voids are distributed in it.

According to Table 6, 100% of foam gives 7.21% of water absorption while 75%, 50% and 25% gives the amount of 3.31%, 2.46%, and 1.4% of water absorption respectively.

Generally, aerated lightweight concrete are porous and will have higher water absorption compared to the normal concrete. However it can be avoided if autoclave curing is used (Short, 1978).

Besides that, different foam agent and water ratio will also affect the water absorption ratio. This can be seen through Figure 7 which shows that foam agent and water ratio of 1:40 gives the higher water absorption compared with 1:30 and 1:25 ratio. According to Table 7, water absorption of 1:40 ratio is 4.46%, 1:30 is 3.31% and 1:25 is 2.6%. The differential between the water absorption of 1:40 and 1:30 ratio is 25.78%. This shows that even though the compressive strength between 1:40 and1:30 ratios doesn't differ that much; 0.68% but the water absorption is very much differ. It can be conclude that, foam agent and water ratio of 1:30 is more suitable since the water absorption is much lesser to compare with 1:40.

The high water absorption of the concrete will also affect the density and compressive strength of the concrete. According to Short (1978), lightweight concrete used in water has to be protected by suitable material in order to avoid or may be reduce water absorption of the concrete.

4.5 SUPPLEMENTARY TEST.

Moisture test and comparison between hardened and wet concrete is another supplementary test in this research. Figure 8 show that different percentage of foam will give different percentage of moisture content as well. It can be seen that moisture content is increased when percentage of foam is increased too. 100% of foam gives the highest moisture content followed by 75%, 50%, and 25% of foam. The explanation for this differential will be the same with the water absorption case where the increasing of voids that caused by the increment of percentage of foam will caused the moisture content to increased accordingly. According to Table 8, moisture content for 100% of foam mixture is 15.3%, while 75%, 50%, and 25% is 10.36%, 9.82%, and 8.93% respectively.

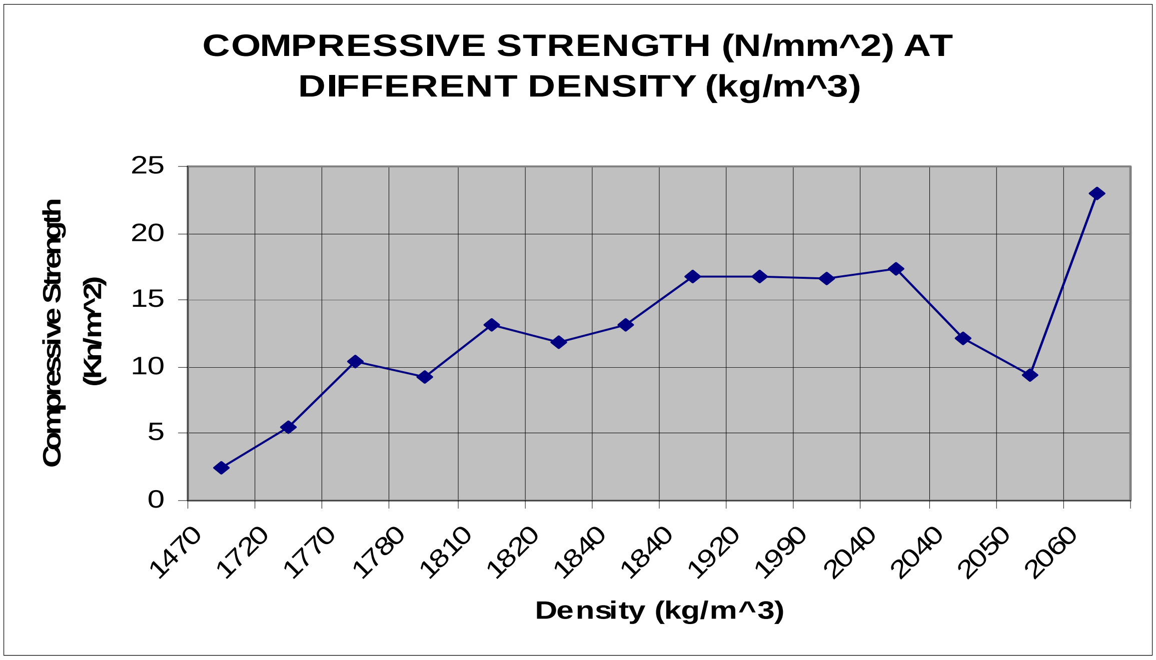

Figure 1: Compressive Strength at Different Density of Hardened Concrete

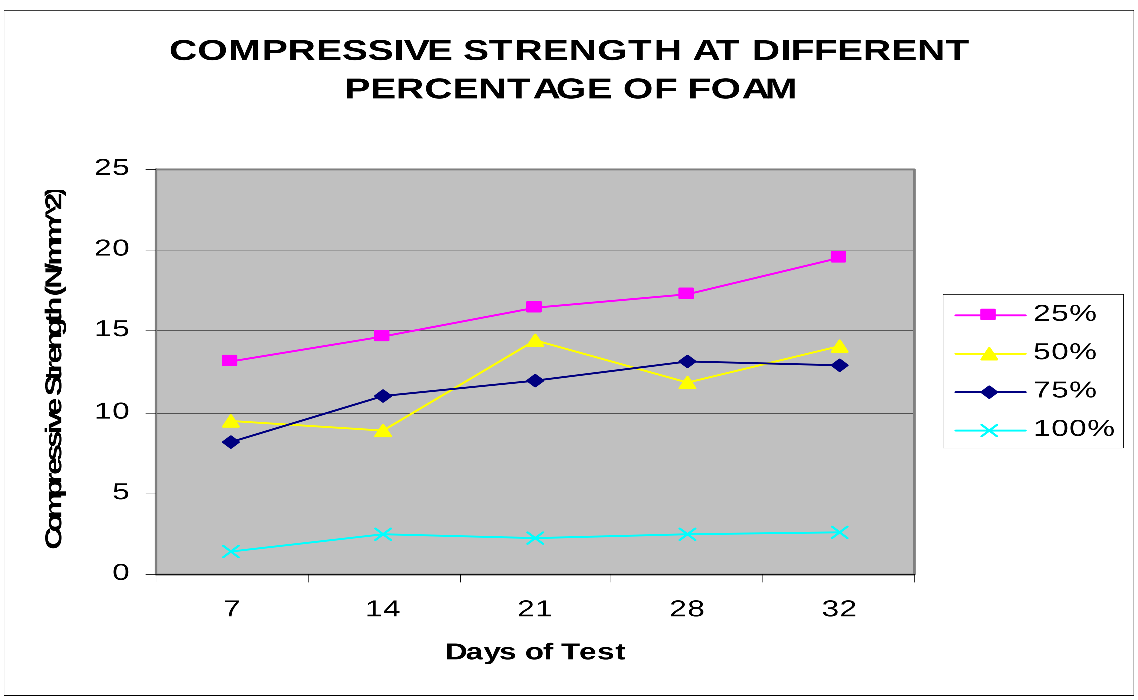

Figure 2: Compressive Strength at Different Percentage of Foam

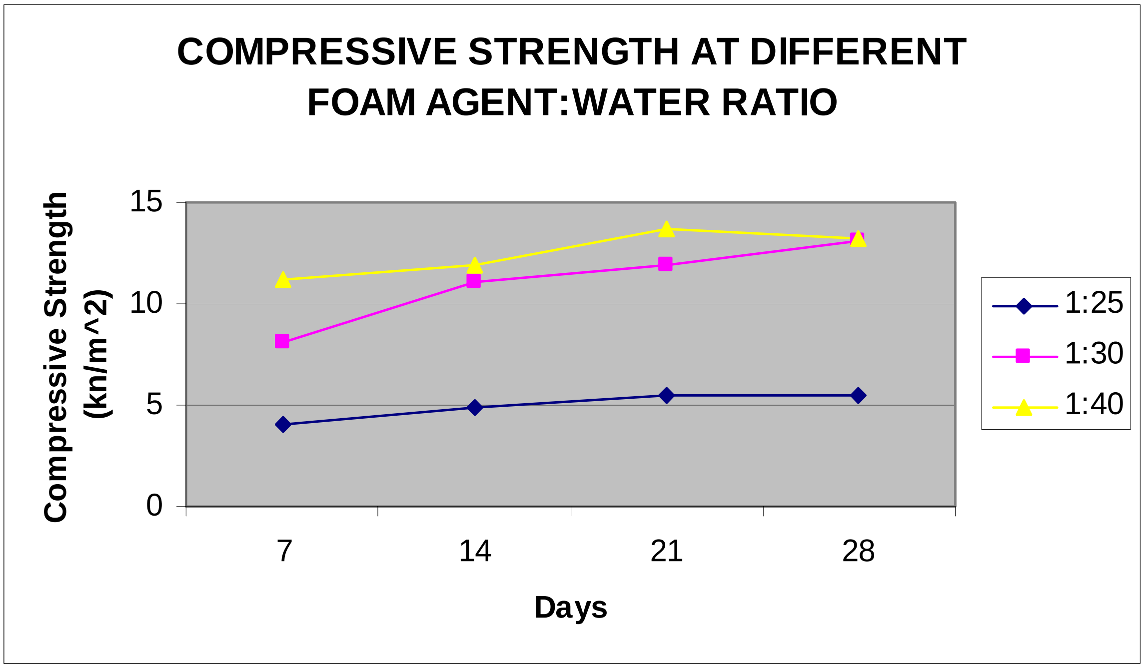

Figure 3: Compressive Strength at Different Foam Agent And Water Ratio

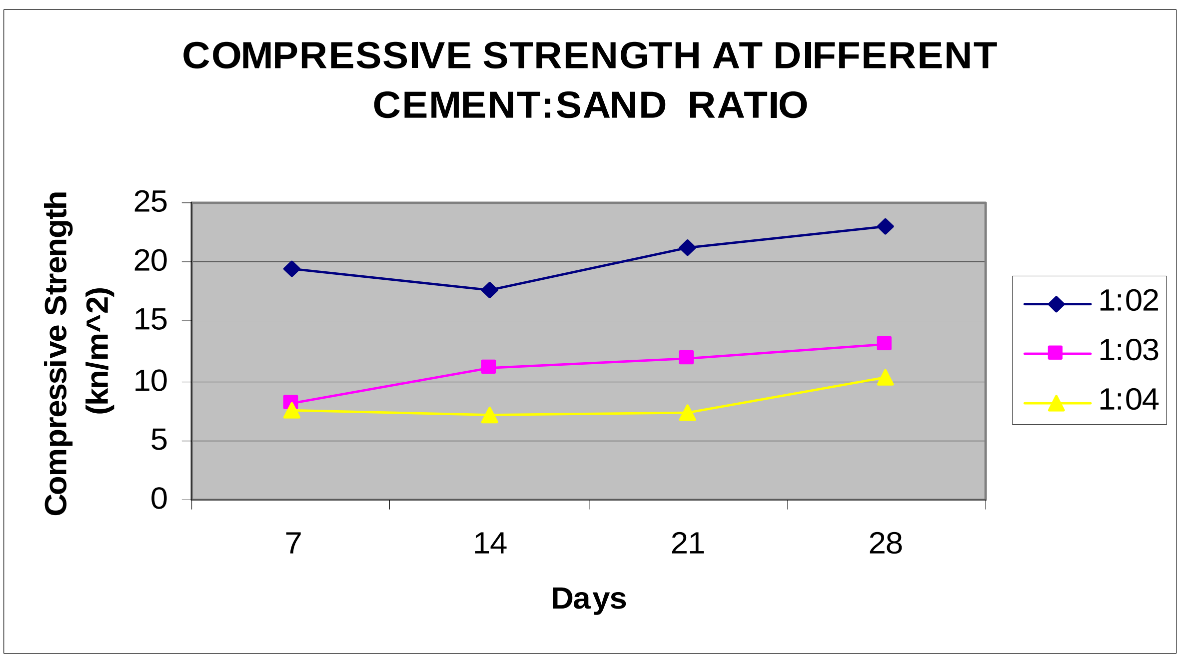

Figure 4: Compressive Strength at Different Cement And Sand Ratio

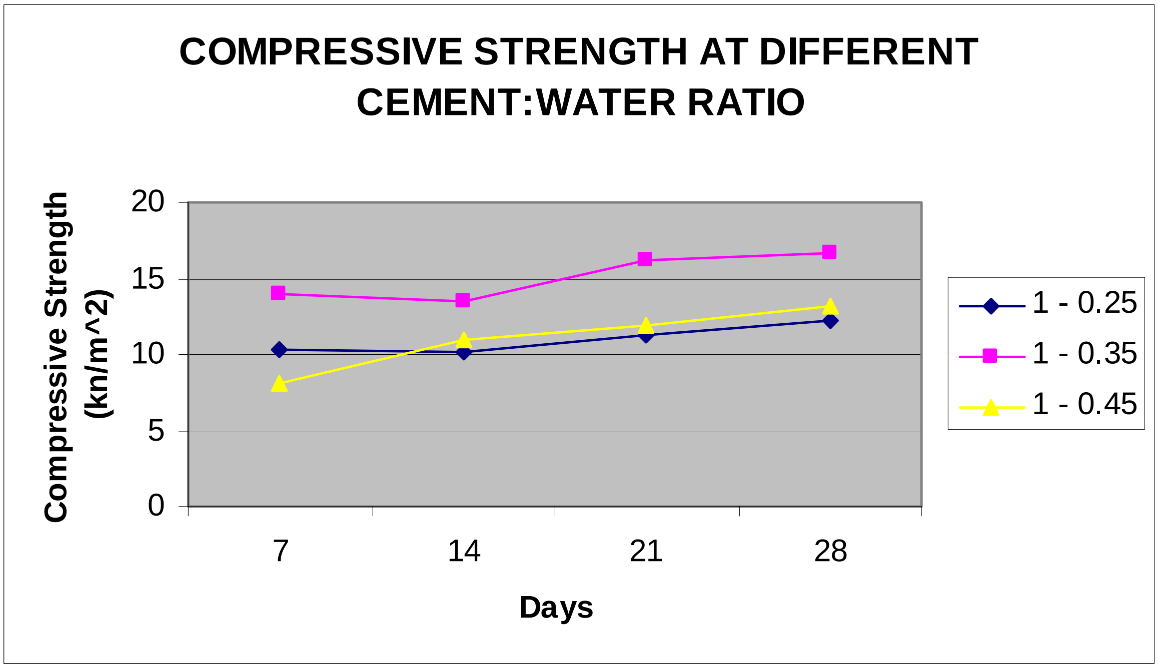

Figure 5: Compressive Strength at Different Cement And Water Ratio

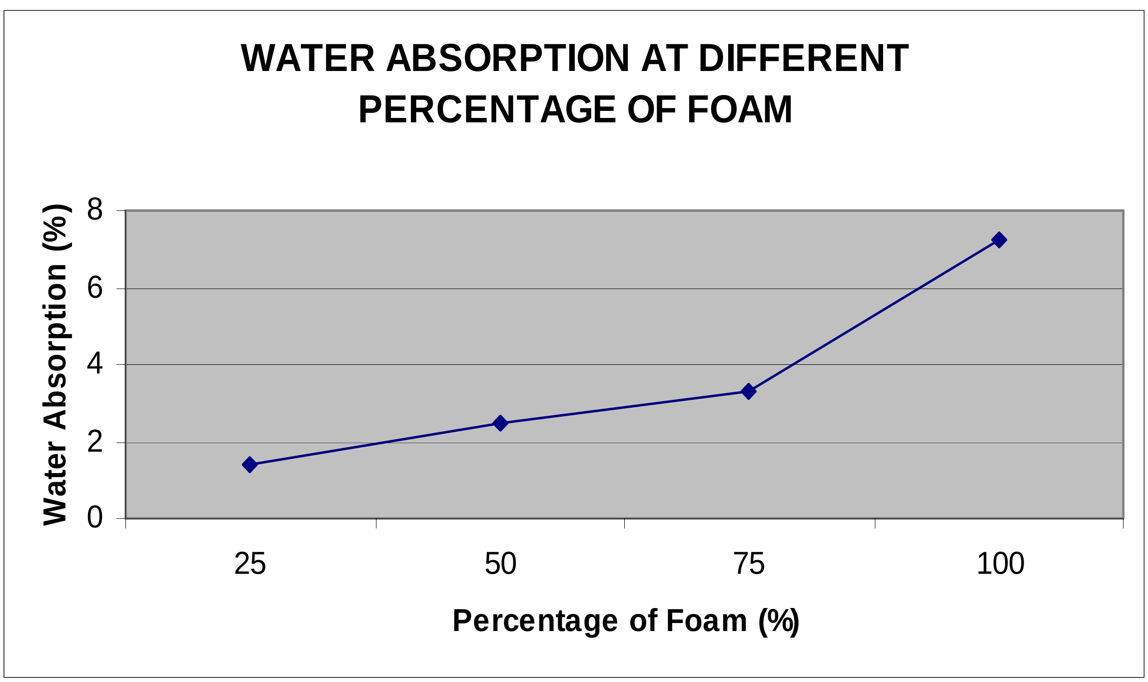

Figure 6: Water Absorption at Different Percentage of Foam

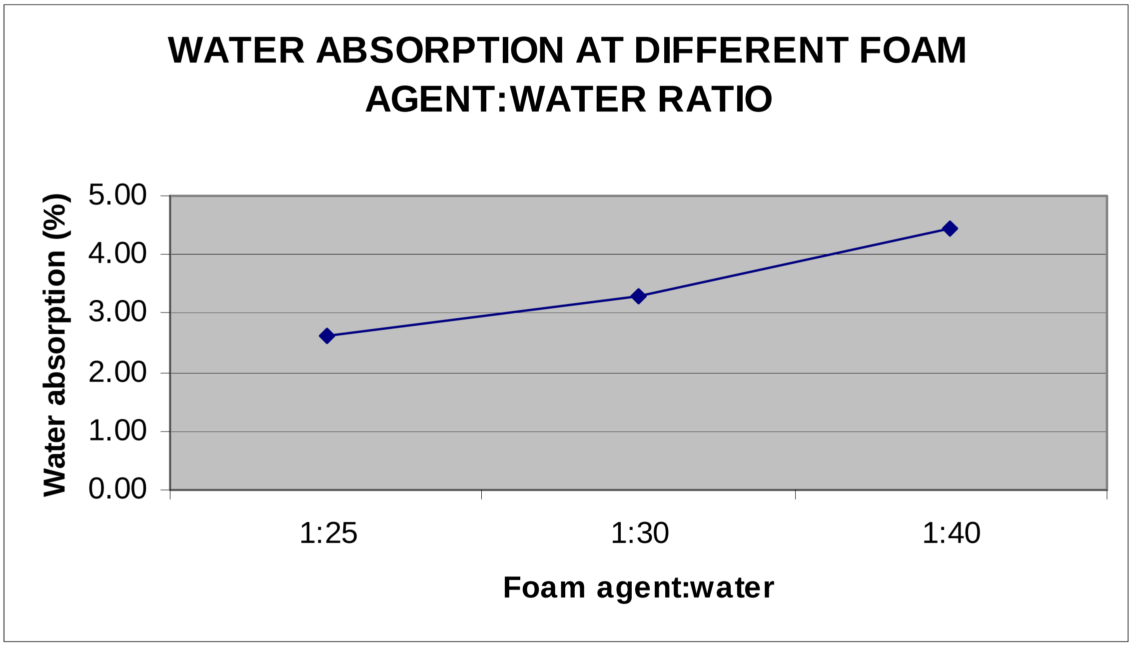

Figure 7: Water Absorption at Different Foam Agent And Water Ratio

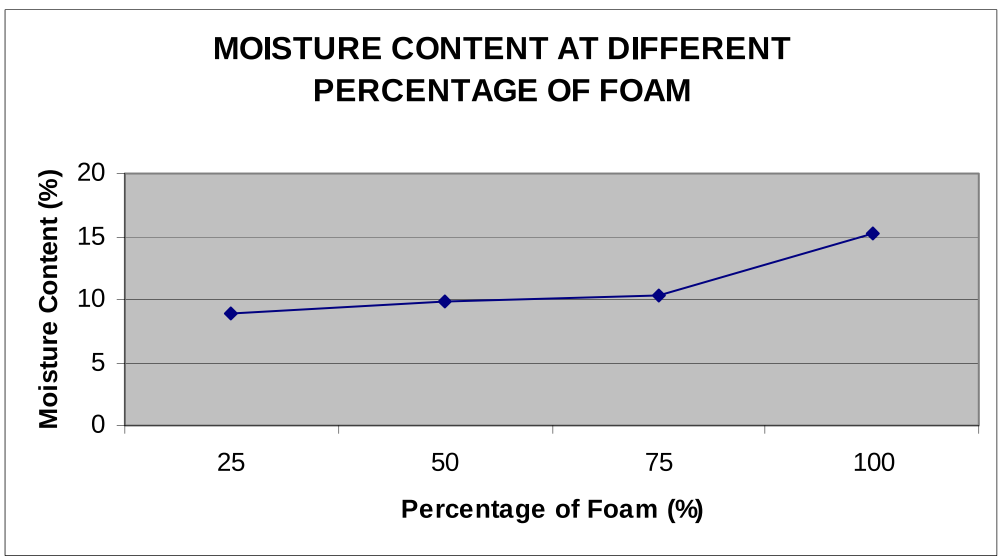

Figure 8: Moisture Content at Different Percentage of Foam

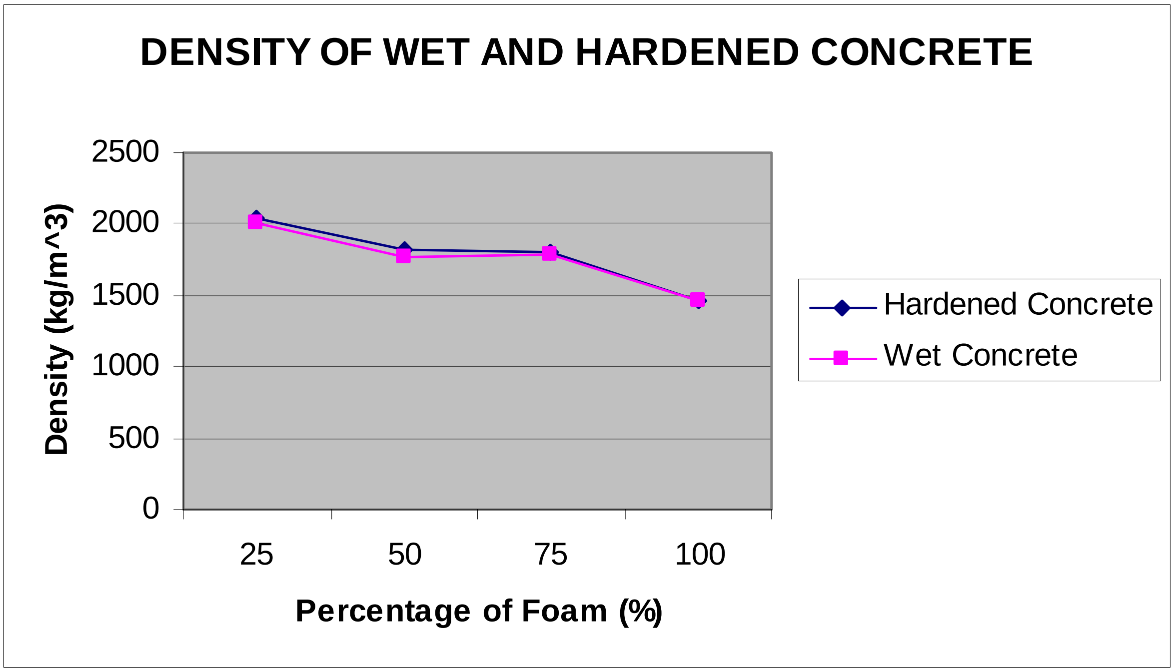

Figure 9: Density of Wet and Hardened Concrete

Density (kg/m^3)	Compressive Strength (kn/m^2)
1470	2.52
1720	5.5
1770	10.34
1780	9.19
1810	13.12
1820	11.87
1840	13.21
1840	16.78
1920	16.73
1990	16.58
2040	17.27
2040	12.18
2050	9.35
2060	22.99

Table 1: Density of Hardened Concrete and Compressive Strength at 28 days.

Days	Compressive Strength (kn/m^2)			
	25% Foam	50% Foam	75% Foam	100% Foam
7	13.2	9.45	8.12	1.43
14	14.68	8.88	11.02	2.44
21	16.41	14.42	11.96	2.23
28	17.27	11.87	13.12	2.52
32	19.53	14.14	12.89	2.62

Table 2: Compressive Strength for Different Percentage of Foam.

Days	Compressive Strength (kn/m^2)		
	1:25	**1:30**	**1:40**
7	4.09	8.12	11.15
14	4.86	11.02	11.95
21	5.45	11.96	13.72
28	5.5	13.12	13.21
Density (kg/m^3)	1720	1810	1840

Table 3: Compressive Strength at Different Foam Agent and Water Ratio

Days	Compressive Strength (kn/m^2)		
	1:2	**1:3**	**1:4**
7	19.44	8.12	7.57
14	17.58	11.02	7.16
21	21.28	11.96	7.44
28	22.99	13.12	10.34
Density (kg/m^3)	2060	1810	1770

Table 4: Compressive Strength at Different Cement and Sand Ratio

Days	Compressive Strength (kn/m^2)		
	1 : 0.25	**1 : 0.30**	**1 : 0.45**
7	10.29	13.91	8.12
14	10.12	13.45	11.02
21	11.34	16.14	11.96
28	12.18	16.73	13.12
Density (kg/m^3)	2040	1920	1810

Table 5: Compressive Strength at Different Cement and Water Ratio

% Of Foam	Water Absorption (%)
25	1.4
50	2.46
75	3.31
100	7.21

Table 6: Water Absorption at Different Percentage of Foam

Foam Agent : Water	Water Absorption (%)
1:25	2.60
1:30	3.31
1:40	4.46

Table 7: Water Absorption at Different Foam Agent and Water Ratio

% Of Foam	Moisture Content (%)
25	8.93
50	9.82
75	10.36
100	15.3

Table 8: Moisture Content at Different Percentage of Foam

Percentage of Foam (%)	Density (kg/m^3)	
	Hardened Concrete	Wet Concrete
25	2040	2000
50	1820	1770
75	1810	1790
100	1470	1460

Table 9: Density of Hardened and Wet Concrete at Different Percentage of Foam

Cement : Water	Cement : Sand	Foam Agent : Water	Foam (%)	Density (kg/m^3)	Strength (N/mm^2)				Moisture Content (%)	Water Absorption (%)
					7 days	14 days	21 days	28 days		
1: 0.45	1 : 3	1: 30	100	1470	1.43	2.44	2.23	2.52	15.3	7.21
			75	1810	8.12	11.02	11.96	13.12	10.36	3.31
			50	1820	9.45	8.88	12.42	11.87	9.82	2.46
			25	2040	13.2	14.68	16.41	17.27	8.93	1.4
		1: 25	50	1990	13.72	12.7	15.29	16.58	7.18	1.73
			75	1720	4.09	4.86	5.45	5.5	10.17	2.6
		1: 40	50	1780	6.38	7.56	8.72	9.19	11.81	2.97
			75	1840	11.15	11.95	13.72	13.21	8.79	4.46
	1 : 4	1: 30	50	2050	8.1	9.49	10.19	9.35	7.85	
			75	1770	7.57	7.16	7.44	10.34	7.98	
	1 : 2		50	1840	10.9	12.55	15.84	16.78		
			75	2060	19.44	17.58	21.28	22.99		
0 : 0.35	1 : 3		75	1920	13.91	13.45	16.14	16.73		
0 : 0.25			75	2040	10.29	10.12	11.34	12.18		

Table 10: Properties of Lightweight Concrete

CHAPTER 5 : CONCLUSION

5.0 CONCLUSIONS

The initial findings have shown that the lightweight concrete has a desirable strength to be an alternative construction material for the industrialized building system.

The strength of aerated lightweight concrete are low for lower density mixture. This resulted in the increment of voids throughout the sample caused by the foam. Thus the decrease in the compressive strength of the concrete.

The foamed lightweight concrete is not suitable to be used as non-load bearing wall as the compressive strength is 27% less than recommended. Nevertheless the compressive strength is accepted to be produced as non-load bearing structure.

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APPENDIX 1

<u>CUBE TEST</u>

Objective:
-To determine the compressive strength of a lightweight concrete sample.

Apparatus:
- Standard cube size 100mm^3
- Steel rod measured 25x25 mm^2

General note:
- Compressive strength will be determined at the age of 7 and 28 days.
- 3 samples for each age will be prepare
- Average result will be taken

Procedure:
1. Prepare the mould; apply lubricant oil in a thin layer to the inner surface of the mould to prevent any bonding reaction between the mould and the sample (A.M Neville, 1994)
2. Overfill each mould with sample in three layers (Standard Method: BS 1881: Part 3: 1970)
3. Fill 1/3 of the mould with sample. This would be the first layer
4. Compact sample with at least 35 strokes using steel rod. Compaction should be done continuously
5. Fill 2/3 of the mould; second layer. Repeat step 4.
6. Continue with the third layer and repeat the same compaction step
7. After compaction has been completed, smooth off by drawing the flat side of the trowel (with the leading edge slightly raised) once across the top of each cube
8. Cut the mortar off flush with the top of the mould by drawing the edge of the trowel (held perpendicular to the mould) with a sawing motion over the mould
9. Tag the specimen, giving party number, and specimen identification
10. Store cube in moist closet (temperature; 18˚C - 24˚C) for 24 hours
11. Open mould and preserved cube in water (temperature; 19˚C - 21˚C) – BS 1881; Part 3: 1970
12. Test cube for 7 days and 28 days accordingly
13. Placed cube on the testing machine: cube position should be perpendicular with its pouring position (A.M. Neville, 1994)
14. Without using any capping material, apply an initial load (at any convenient rate) up to one-half of the expected maximum load (G.E. Troxell, 1956)
15. Loading should be increased at a uniform increment; 15 MPa/min (2200 Psi/min) – BS 1881: Part 4: 1970. Since that certain sample are expected to have lower compressive strength, some adjustment will be made; loading will be increased with the increment of 5% of the expected maximum compressive strength
16. When it comes nearer to the expected maximum strength, loading increment will be lessen little by little (A.M. Neville, 1994)

APPENDIX 2

BS Absorption Test

Objective:

- To determine the absorption capacity of lightweight concrete sample

Apparatus:

- A balance
- An air tight vessel
- A container of water
- An oven

General note:

- Test will be carried out on 75 mm diameter (± 3mm) specimens
- Specified test age is 28-32 days.
- 3 samples for each age will be prepare
- Average result will be taken

Procedure:

1. Dry the specimens in an oven at 105˚C ± 5˚C for 72 ± 2 hr.
2. Cooled specimen for 24 ± 1/2 hr in an airtight vessel
3. Weight the specimen
4. Immersed horizontally in the tank of water at 20˚C ± 1˚C with 25 ± 5 mm water over the top surface
5. Immersed for 30 ± ½ minutes
6. Removed specimen
7. Shaken and dried quickly with a cloth to remove free surface water
8. Weight the specimen again

Calculation:

Absorption capacity can be calculate using the formula given below:

$$\boxed{\text{Absorption Capacity} = \frac{\text{Increased In Weight (kg)}}{\text{Weight of Dry Specimen (kg)}} \times 100\%}$$

APPENDIX 3

Simple Density Test.

Objective:

- To determine the density of hardened lightweight concrete sample.

Apparatus:

- Weighing scale
- One cube sample

General Note:

- For more economic sample are to be taken from compression test sample; before doing the test
- Three sample are going to be used and average result will be taken

Procedures:

1. Weight sample using weighing scale
2. Get the average weight of those 3 samples
3. Calculate the density using the formula given below

$$\text{Density} = \frac{\text{Average Weight Of Samples (kg)}}{\text{Volume of Sample (m}^2\text{)}}$$

(Since a standard mould; 100 x 100 x 100 mm is used, volume of each sample can be determined according to this dimensional)