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STRENGTH PROPERTIES OF FOAMED CONCRETE IN DIFFERENT CURING MEDIUM

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ABSTRACT

Foamed concrete is a lightweight concrete formulated from a mixture of concrete mortar and stabilised foam. Generally foamed concrete is known for its low engineering properties and susceptible to harsh environmental condition. This paper discuss the outcome of a laboratory experiment on properties of foamed concrete using fine quarry produced aggregates with density between 1200kg/m^3 to 2000kg/m^3. Specimens were cured with three different medium which are air, fresh water and salt water. From the experiment, specimen cured with salt water gives more strength and durability compared to others. This concludes that foamed concrete shows higher resistant to harsh environmental condition such as exposure to salt water. It is also shown that the value of strength and durability increased as the density increases regardless the type of curing medium used. Increasing the density will contribute to increasing the strength and resilience of the foamed concrete.

Keywords: lightweight concrete, foamed concrete, compressive strength flexural strength

1. INTRODUCTION

Concrete is a widely used composite material in the construction industry replacing the used of timber and steel. Concrete is a mixture of cement, aggregates and water in certain ratio. Normally the density of concrete is between 2240 to 2600kg/m^3 (Short, 1978;Neville, 1994). Normal concrete is heavy thus contribute to increasing the dead load of a structure. It is also difficult to place since compaction is needed and this requires specialised equipment. Hardened concrete is difficult to cut or nailed unless certain specialised equipment is used. Some users complain that concrete is cold and damp.

Low density concrete which also known as lightweight concrete could be an alternative to normal concrete. This also could add more choice to consumer. Foamed concrete is a type of lightweight concrete produce by mixing cement, fine aggregate and stabilised foam. Foam added to concrete mortar will form cellular void to the matrix once it's set. This cement matrix is similar to sponge cake which happened to have fine cellular void with diameter between 0.1–1mm (Neville, 1994). Foam added to the mixture will increase the volume of concrete produced thus resulting in lower density and lighter concrete. This is actually a cement mortar since the absent of coarse aggregate, but generally it is known as foamed concrete.

According to the draft of *International Standard Model Code for Concrete Construction (1977)*, the density of lightweight concrete is between 1200 to 2000kg/m^3. However, foamed concrete can be produce with density as low as 300kg/m^3. *America Concrete Institute 116R-87* stated that lightweight concrete can be divided into three categories according to their density namely low, medium and high. Those which density is lower than 800kg/m^3 are categories as low-density. The low-density group normally have compressive strength between 0.35 to 6.9N/mm^2 and used as insulation material. Medium-density group has density between 800 to 1440 kg/m^3 with compressive strength between 6.9 to 17.3N/mm^2 and commonly used in non-structural concrete application. The high-density group has density between 1440 to 1900kg/m^3 with compressive strength exceeding 17.3 N/mm^2 and could be reaching up to 62.1N/mm^2 which can be used as structural material (Jones,McCarthy, 2005).

Previous study shows the strength of concrete will increase with the increase of its density, high

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density concrete will give high compressive strength. The study also shows that the strength of concrete will decrease when exposed to aggressive environment such as salt water as compared to fresh water and air. This paper will discuss the result from a laboratory test on specimens of foamed concrete cured with three different medium which are air, fresh water and salt water.

2. STUDY PROGRAM

- ***Study parameter and design mix***

Table 1: Design mix for 1m^3.

Target density - dry density *(kk)* (kg/m^3)	Wet density *(kk*+100) (kg/m^3)	Cement (kg)	Aggregate (kg)	Foam (litre)	Additive (1% of cement weight) (kg)	Water-cement ratio	Slump test (mm)
2000	2100	714	1071	58	7.14	0.39	160
1800	1900	667	1001	148	6.67	0.39	160
1600	1700	588	882	238	5.88	0.39	160
1400	1500	526	789	327	5.26	0.39	160
1200	1300	455	683	417	4.55	0.39	160

The objective of this study is to evaluate the strength of foamed concrete cured with different medium, which are air, fresh water and salt water.

Design mix for producing 1m^3 foamed concrete is shown in Table 1. This design mix is based on cement-aggregate ratio of 1:1.5 by weight. Five design mixes prepared to archive target density of 1200,1400,1600,1800 and 2000kg/m^3. Wet density of the concrete mixture was prepared 100kg/m^3 higher to compensate drying process.

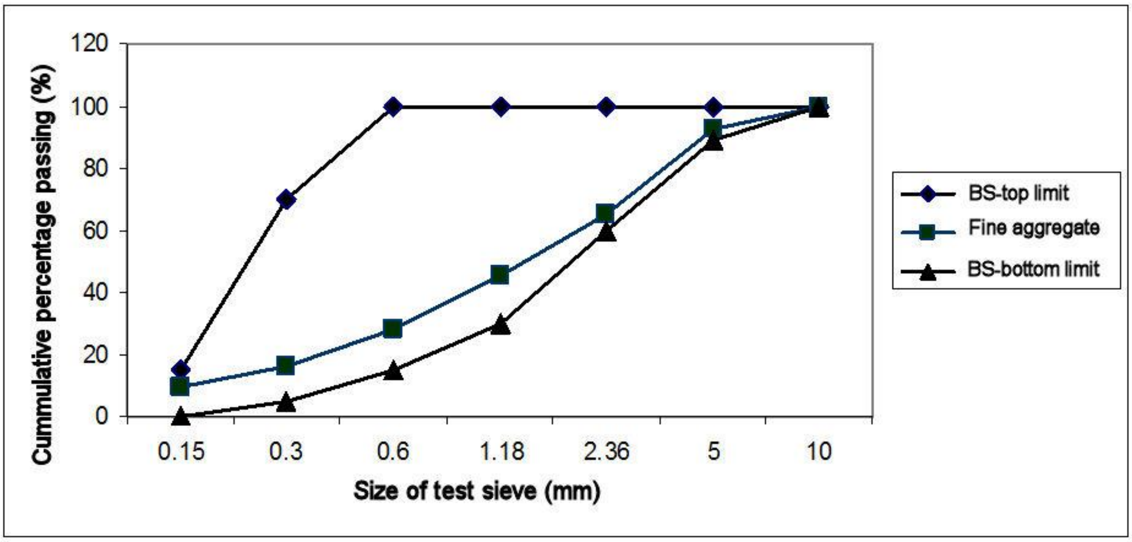

Figure 1: Sieve analysis for fine quarry produced aggregate

- ***Material***

Ordinary Portland cement was used as concrete binder. Manufacturing process of this cement is compliant to British Standard BS12:1978 (BSI, 1978). Aggregate will take the most of concrete volume which is about 70% or more. In this study, fine quarry produced aggregate was used with maximum particle size of 5mm. Sieve analysis for the fine aggregated used in this experiment are shown in Figure 1. Fine quarry produced aggregate used is comparable in term of quality to normal river fine sand and it is much cheaper (Ramli, 1991). The fine aggregate used in this experiment is shown in Figure 2. Foaming agent that has been used is Noraite PA-1 (Additive for the manufacture of lightweight concrete) or also known as ‘Deecell’ manufactured by Unisains Holding Sdn. Bhd. The foaming agent is based on protein extract from animal and plant. The foaming agent will be diluted with water in the ratio of 1:19. The density of the foam produced was specified by the manufacturer between 75 to 80g/l (ASTM, 1997). Figure 3 shows stable foam produced from Portafoam generator that being used in this experiment. Plasticizer additive is being used in the experiment to reduce water cement ratio and increase concrete strength. Additive 'Admix SP 1000' was added at 1% of cement weight to the concrete mixture. Tap water is being used with pH reading between 6.5 to 8.5. Water is a very important substance to react with cement to produce hydrated cement.

3. METHODOLOGY

Uniformity in preparing the concrete mixtures according to their design mix is very crucial. Raw materials are prepared and measured with correct amount. Mix preparation procedure is the same as normal mortar or concrete mix preparation, except foam is added at the end of the process with correct amount needed. Slump test will be performed on fresh foamed concrete produced as required by ASTM C230-98 (ASTM, 1998). Slump test reading should be between 180–200mm and cannot be lower than 160mm. If the result is satisfied than foamed concrete will be placed into moulds. When poured, the foamed concrete will flow in and fill the mould without the need to be compacted. After 24 hours, the specimens will be taken out from the mould. Specimens will be cured in three different medium which are air, salt water and fresh water for the duration of 7, 28, 90, 180 and 365 days.

Figure 2: Fine quarry produced aggregate

Figure 3: Foam from Portafoam

Two types of test have been conducted which are compressive strength test and flexural strength test. Compressive strength test are conducted based on BS 1881: Section 116:1983 (BSI, 1983). Specimens prepared for this test are 100x100x100mm sized cube as shown in Figure 4. For evaluating the flexural strength, tests are conducted according to BS 1881: Section 118:1983 (BSI, 1983) or MS7.1: Section 4: 1971 on 100x100x500mm sized prism as shown in Figure 5.

4. RESULTS AND DISCUSSIONS

- ***Compressive strength test***

Table 2 and Figure 6-8 shows the compressive strength test result. Specimens cured with salt water give higher strength value compared to those were cured in air and fresh water for every age of specimens namely 7, 38, 90, 180 and 365 days and at every target density, 1200, 1400, 1600, 1800 and 2000kg/m^3. The highest compressive strength showed by specimen with density of 2000kg/m^3 at 365days of age. Specimen cured with salt water gives compressive strength value of 48.86N/mm^2, this is 4.68% higher than those that cured by fresh water and 15.21% higher than specimen cured by air. The lowest value recorded is at the age of 7 days for specimens with density of 1200kg/m^3, specimen cured with salt water gives compressive strength reading at 2.88N/mm^2, this however 5.21% higher than specimen cured in fresh water and 10.10% higher than the strength of specimen cured in air.

Figure 4: Compressive strength test

Figure 5: flexural strength test

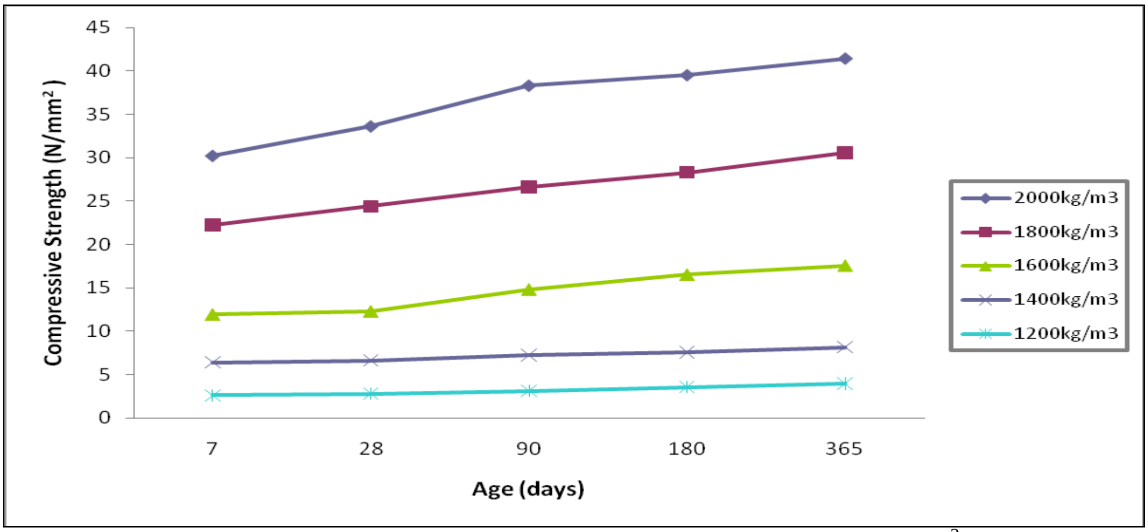

Figure 6: Compressive strength for specimens cured in air (N/mm^2).

This result generally shows that foamed concrete archive higher compressive strength when cured with salt water followed by fresh water and air. This is caused by the matrix bond in foamed concrete that being cured by salt water are closer and stronger compared to those were cured in fresh water and air. The test result also shows that higher density of foamed concrete will gives higher compressive strength. The increase of specimen age also contributes to the increase of compressive strength for all specimens regardless the curing medium used.

Table 2: Compressive strength test result (N/mm^2).

Target Density (kg/m^3)	Curing medium	Age				
		7	28	90	180	365
2000	Air	30.24	33.63	38.31	39.52	41.43
	Fresh water	35.21	38.15	42.70	44.85	46.62
	Salt water	38.29	41.05	44.38	46.82	48.86
1800	Air	22.23	24.38	26.63	28.31	30.54
	Fresh water	24.57	26.21	28.57	30.87	32.45
	Salt water	25.12	27.56	29.69	31.28	33.12
1600	Air	11.92	12.28	14.82	16.52	17.56
	Fresh water	14.67	16.31	18.68	20.73	21.25
	Salt water	16.35	18.27	20.52	21.35	23.78
1400	Air	6.39	6.62	7.21	7.56	8.15
	Fresh water	6.57	7.32	7.70	7.95	8.21
	Salt water	7.35	8.17	8.44	8.72	9.03
1200	Air	2.59	2.78	3.12	3.56	3.94
	Fresh water	2.73	3.03	3.21	3.79	4.02
	Salt water	2.88	3.25	3.46	4.02	4.58

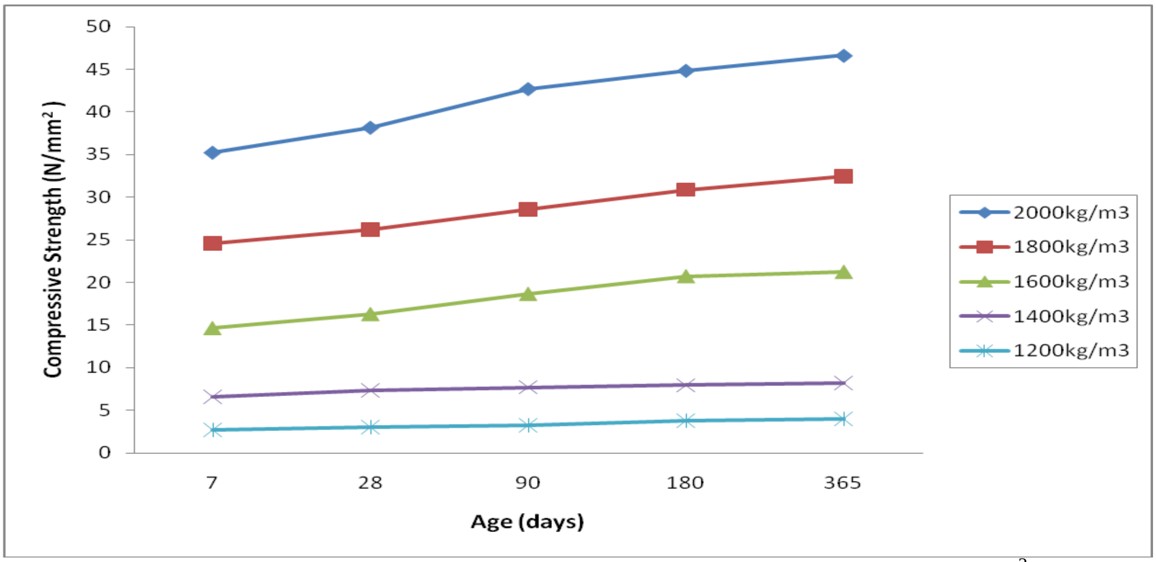

Figure 7: Compressive strength for specimens cured with fresh water (N/mm^2).

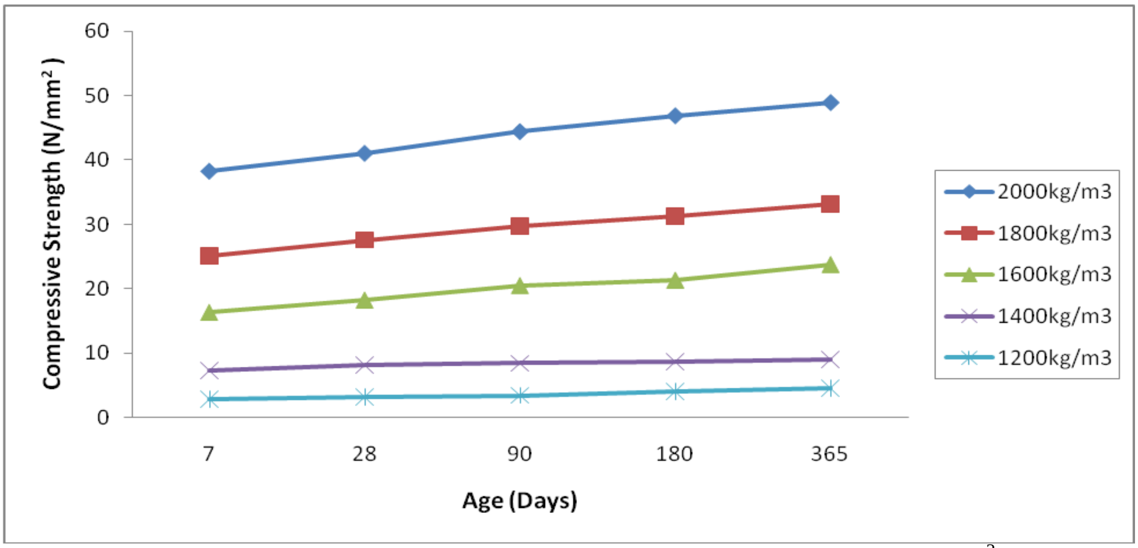

Figure 8: Compressive strength for specimens cured in salt water (N/mm^2).

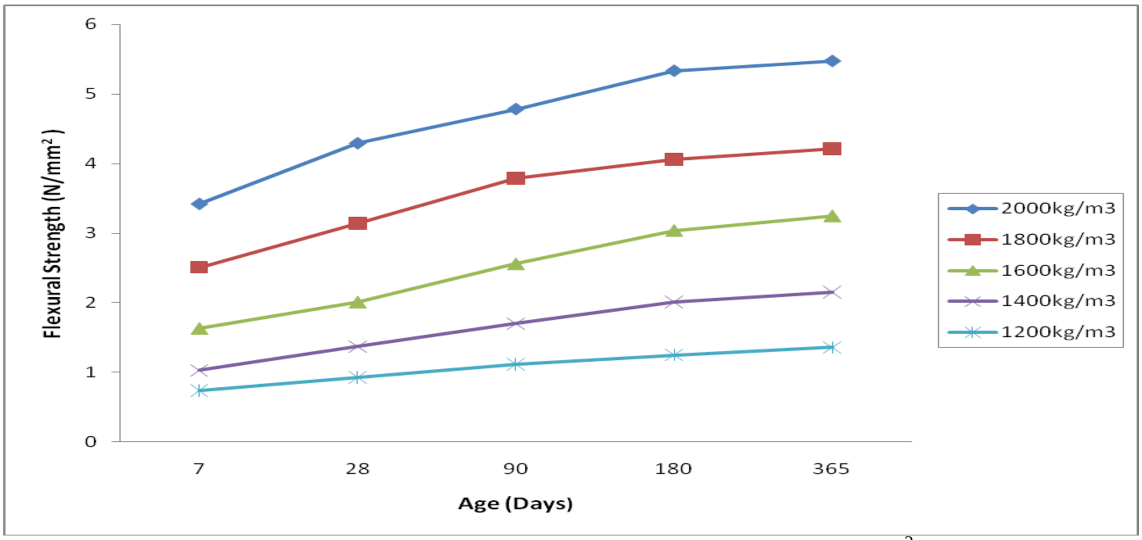

Figure 9: Flexural strength for air cured specimens (N/mm^2).

- ***Compressive strength test***

Table 3 and Figure 9-11 show the flexural strength results. Curing with salt water gives higher value of flexural strength compared to other curing medium for all specimens age which are 7, 28, 90, 180 and 365 days and across all target density tested; 1200, 1400, 1600 and 2000kg/m^3. The highest flexural strength recorded at age of 365days for 2000kg/m^3 density specimens. Flexural strength for specimen cured with salt water is 8.25N/mm^2 which is 7.03% higher compared to specimen cured with fresh water and 33.70% higher compared to those who are air cured. The lowest flexural strength recorded is on specimen with lowest density (1200kg/m^3) and at 7 days of age. Specimen cured with salt water still gives the highest flexural strength reading at 1.02N/mm^2 which is 7.84% higher than fresh water cured specimen and 27.45% higher than air cured specimen. The result generally shows that foamed concrete will gives higher flexural strength when cured with salt water followed by specimens cured with fresh water and air. This condition is caused by the bond in the concrete matrix cured with salt water are much closer and stronger than specimens cured with fresh water and air. The results also show that higher density foamed concrete is stronger than the lower density specimens. The increase of specimens' age will also contribute to increase in flexural strength regardless the curing medium used.

Table 3: Flexural strength (N/mm^2).

Target density (kg/m^3)	Curing medium	Age (days)				
		7	28	90	180	365
2000	Air	3.42	4.29	4.78	5.33	5.47
	Fresh water	5.50	6.53	6.87	7.09	7.67
	Salt water	5.81	6.90	7.24	7.73	8.25
1800	Air	2.51	3.14	3.79	4.06	4.21
	Fresh water	3.62	4.10	4.38	4.67	5.80
	Salt water	3.89	4.42	4.83	5.61	6.12
1600	Air	1.63	2.01	2.56	3.04	3.25
	Fresh water	2.01	2.37	2.79	3.28	3.94
	Salt water	2.34	2.58	2.96	3.70	4.51
1400	Air	1.03	1.37	1.70	2.01	2.15
	Fresh water	1.67	1.99	2.17	2.48	2.64
	Salt water	1.75	2.10	2.31	2.63	2.88
1200	Air	0.74	0.93	1.12	1.25	1.36
	Fresh water	0.94	1.11	1.23	1.34	1.42
	Salt water	1.02	1.21	1.35	1.41	1.53

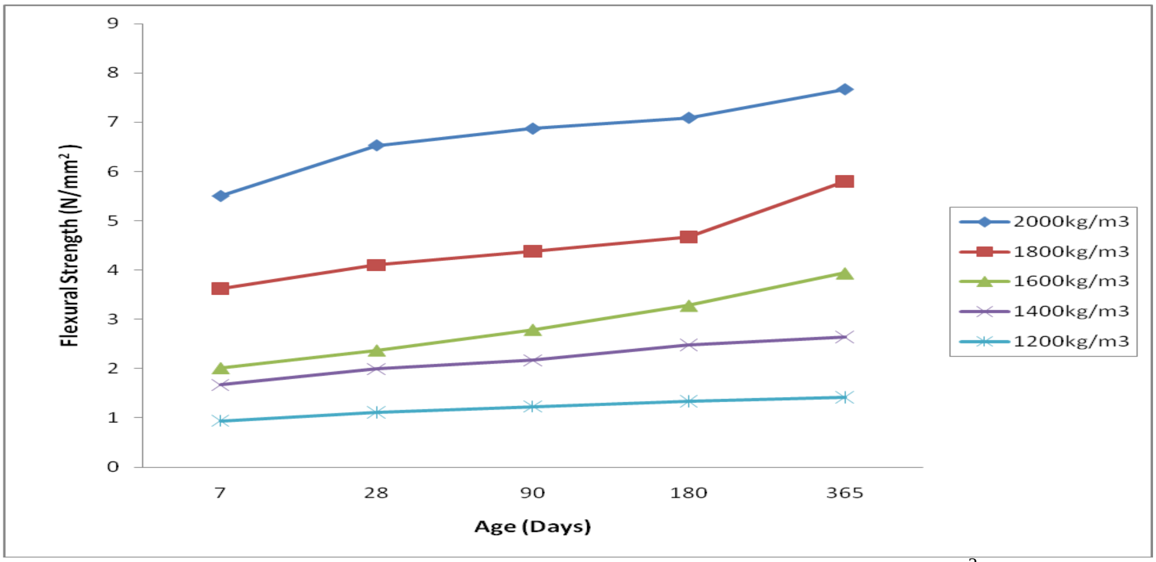

Figure 10: Flexural strength for fresh water cured specimens (N/mm^2).

5. CONCLUSIONS

This study shows that foamed concrete will gives different strength depending on its density. Higher density will give higher compressive and flexural strength. The density of foamed concrete is controlled by the amount of stabilised foam added during the mixing process. The various density and strength properties of foamed concrete will contribute to wide variety of usage such as insulation material, non-structural application and structural application. Different curing medium also affect the strength properties of foamed concrete. Curing with salt water will gives higher compressive and flexural strength compared to curing with fresh water and air. This shows that foamed concrete could be stronger when exposed to aggressive condition such as salt water. This condition is caused by the crystallization of salt water that has seep into the foamed concrete matrix. The crystallization process has enhanced the bond between molecules inside the concrete matrix. The same process also happened in fresh water cured concrete but the bond is weaker than salt water. Obvious shrinkage can be observed on air cure foamed concrete and this contribute to lower strength. Therefore, foamed concrete is suitable for use in aggressive environments such as costal and marine area. (Wan Alwi,2009).

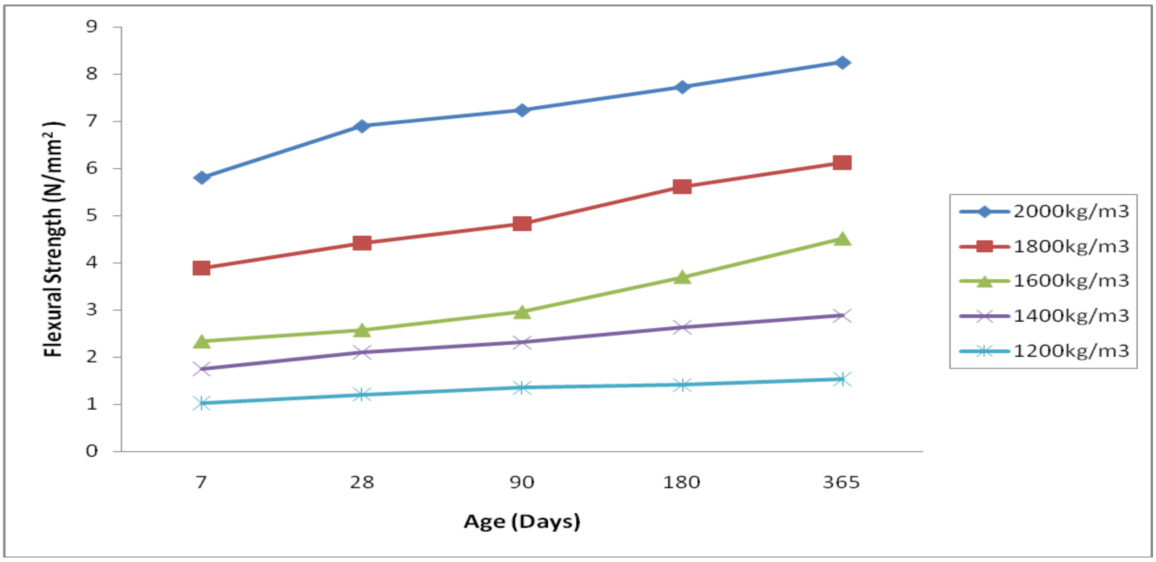

Figure 11: Flexural strength for salt water cured specimens. (N/mm^2)

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