Effects of Aggregate Size on Concrete Tensile Strength

by

Mohd Amin Bin Muktar

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

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CERTIFICATION OF APPROVAL

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December 2007

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Amin Bin Muktar

ABSTRACT

Concrete properties are dependant on many factors and one of them is the aggregate. Aggregates play a major role to the concrete properties as it present most of the concrete volume. Aggregate can affects both fresh and hardened concrete properties. Some of the major aggregate properties that influenced concrete structures are the size, particle shape, surface texture, bulk density and its water absorption. In this project, concrete mix was design by using one particular size of coarse aggregate and the tensile strength was determined. It is understood that the tensile strength came from the strength of the cement paste to hold the aggregates. By introducing the same and smaller size of aggregates, more surface area for the cement paste to contact are provided. Other factors affecting concrete tensile strength are porosity, water cement ratio and the cement that being used in the concrete.

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I am grateful to all of those with whom I have had the pleasure to work with during this project. Each of the technicians has provided me extensive personal and professional guidance.

Nobody has been more important to me in the pursuit of this project than my family members. I would like to thank my parent, whose love and guidance are with me in whatever I pursue. They are ultimate role models.

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CHAPTER 1

INTRODUCTION

1.1 Background

The tensile strength of concrete is used as design parameter in different ways in design codes. Tensile strength values associated with the characteristic compressive strengths classes are explicitly defined in most codes. Even so, the direct application of the tensile strength as design parameter varies. Direct applications are mainly used in the following design situations:

Ultimate Limit State

- Shear strength and punching shear strength
- Shear transfer in cracks

Service Limit State

- Crack formation
- Crack spacing
- Tension stiffening

When the tensile strength is applied as a design parameter in the ultimate limit state, the major concern is to maintain adequate safety. It is generally realized that the effective minimum tensile strength of concrete members may be substantially reduced by environmental effects (restrained shrinkage and temperature differences) construction joints and other crack initiators. Transfer of longitudinal force resultants by the tensile strength of plain concrete is therefore usually not relied upon. However, in cases where the average tensile strength in a certain volume is decisive such as for anchorage of reinforcement, and/or when the tensile stresses are oriented in directions where the concrete is more protected from detrimental effects, such as in slabs subjected to shear, the tensile strength is reliable and should be recognized as a basic strength parameter in ultimate limit state.

1.2 Problem Statement

Generally, concrete was found to be weak in tension that is tensile strength. This condition occurred because of several factors. Most common method to increase the tensile strength of the concrete was by inserting reinforcement bar to the concrete mixture as the steel has very high tensile strength. One of the major constituent in concrete is aggregate. Thus, aggregate properties have significant effects to the concrete properties. Different size of aggregate will be used to study effects of this size to the concrete tensile strength.

1.3 Objectives and Scope of Study

The objective of this project is to study the effects of aggregate size to the concrete tensile strength. The values of this tensile strength will be measured by conducting two lab tests. We will improve the strength by determining the suitable particular aggregate size and proper design mix of the concrete. Other properties of aggregate that contribute to tensile strength also will be studied. Properties of the concrete itself need to be studied in order to understand the tensile strength of concrete and how it can be improved.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Concrete

Concrete were used in modern building projects, from foundations for giant telescope mountings, to nuclear power stations, to garage and patio floors, roads and railway sleepers, shore protectors against wave action, dam walls, and settings for the poles of washing lines and chicken runs. Concrete is also used very successfully in boat building. The fundamental chemistry is much the same in all cases, although the concrete itself may be modified in a variety of ways to adapt its properties to an enormous diversity of design requirements.

Concrete is a mixture of cement, or a cement-like substance, with sand, stones and water. The water is added to the dry components to initiate the chemical changes leading to hardening, after which the strength and durability of the material is comparable to some of the hardest rocks. But, unlike the ages-long geochemical processes involved in rock formation, concrete can be mixed in a few minutes, and will approach its final hardness within a few weeks - or even a few hours if certain chemical accelerators or admixtures are added during the mixing stage.

The main part of the concrete is of course the cement, the substance that, with water, does the chemical work, and binds the sand and stones into a strong, composite material. The sand and stones are referred to as aggregate. Stones are the coarse aggregate and sands were classified as fine aggregate. The stones are usually between about 10 and 20mm in size. Though less important than the quantity of cement involved, the sizes and proportions of the aggregate components are the factors that determine the final properties of the concrete. Both types of aggregate should include particles with widely-varying sizes.

2.2 Proportions and strength

In determining the proportions of sand and stone, the main considerations are physical rather than chemical. The spaces between the stones, the void ratio should be completely filled by the volume of sand. And the small spaces between the sand grains in turn should be filled by the very much smaller particles of the cement. Because the cement, when mixed with water, undergoes the chemical process of changing into a rock-hard, rigid substance, the amounts of cement and water present in the mixture are the main determinants of final strength.

The cement, sand and added water make up a paste, the volume of which should be slightly more than the void volume of the coarse aggregate. Typically, the volume of coarse aggregate (including its void volume) represents about 70-80% of the volume of concrete finally produced. In addition to the proportions of cement to aggregate, there is a close and important relationship between the amount of water used in the mix, and the final strength of the concrete. A sloppy, runny mix produces weak concrete. Usually the volume of water is about the same as the volume of cement in the mix. The problem with making too dry a mix is that it isn't easy to work with, and is likely to have cavities in it when hardened. This condition also will greatly reduce its strength.

2.3 Concrete Strength Development

Figure 1 below shows the development of compressive strength for a concrete as a function of curing time. Rapid increase of strength can be observed during the early period (first week). The strength after one week is more than half that attained at the end of four weeks. After 28 days, the shape of the curve was more like a straight line. The strength still keeps increasing beyond a month but at a very slow rate.

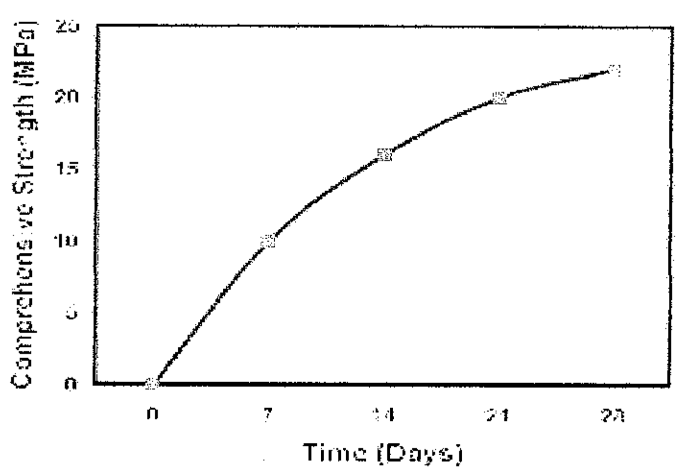

Figure1. Concrete compressive strength vs. time during the curing

The strength unit on the graph is MegaPascals (MPa). The Pascal is the basic unit of pressure, and pressure is defined as force per unit area. The details on the graph were obtained empirically - in other words, from experiments.

2.4 Tensile Strength in Concrete

Tensile strength of concrete has a fundamental role in the fracture mechanism of concrete of hardened concrete. Almost all of fracture in concrete occurs through cracking caused by tensile stresses. This means that concrete fraction is essentially a tensile failure regardless of whether the fracture is caused by compression, freezing or by any other factors. The type of loading controls only the character of the cracking through which the strength and other mechanical properties of concrete are influenced.

In the practice, tensile strength is most commonly utilized in beams and slabs. The tensile stresses are caused by tensile or flexural loads, temperature changing shrinkage and moisture changes. To avoid undue cracking in the concrete of such structure, tensile strength is really important, despite its low magnitude. Generally, tensile strength of concrete is about one-tenth of compressive strength.

2.5 Aggregates in Concrete

Aggregate was the major constituent in the concrete mixture. It represents 60-80% of the concrete volume. Therefore, aggregate type and volume influences the properties of concrete and its mix proportion. The most important requirement is that the aggregate remains stable within the concrete and in the particular environment throughout the design life of concrete. The characteristic of the aggregate must not affect adversely the performance of concrete in either the fresh or hardened concrete. The most important properties of aggregate are shape and texture and the maximum aggregate size. Since aggregate is generally much stronger than cement paste, the strength of the aggregate is less important when the study was focused on the tensile strength of concrete. That is to say that, tensile failure starts from the bonding of aggregate and cement paste, not from the internal structure of aggregate itself. Texture of the aggregate affects both the bond and the stress level at micro-cracks. This type of behavior will affect the tensile strength but will not affect the compressive strength.

2.5.1 Aggregate Size and Grading

In general, the overall grading of combined coarse aggregates and sand should provide a material having the lowest possible surface area and the void content. This would require the lowest possible water and cement contents to achieve the desired workability, strength and other concrete properties. Figure 2 shows the typical relation between water content, maximum aggregate size and workability. The use of appropriately proportioned coarse aggregates and sand grading normally provides concrete having at least adequate properties in fresh and hardened state.

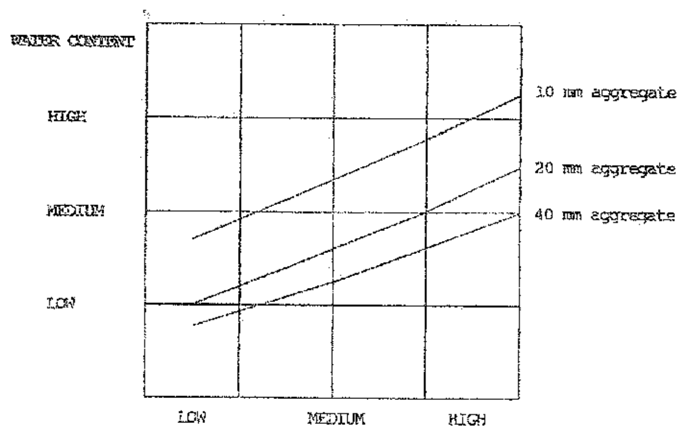

Figure 2. Typical relation between water content, maximum aggregate size and workability [1]

When very coarse aggregates are used, the concrete mix can be harsh and suffer bleeding especially at lower cement content. Very fine aggregates present a conflict between the amount required to ensure that the concrete is sufficiently cohesive and the need to minimize the effect on water demand of the high aggregate surface area (Gaynor 1964).

These problems can be reduced or even eliminated by careful design of the concrete mixes, also by carefully selecting and using air entrainment for coarse aggregate and water reducing admixtures (Concrete Society 1980).

2.5.2 Aggregate Particle Shape

The shape characteristics of coarse aggregates and sand can have marked effects on the properties of both fresh and hardened concrete, these effects tending to be beneficial where the predominant particle shape is generally equidimensional and detrimental where it is flaky or elongated.

Experiments have shown that the workability of concrete as measured by the compacting factor is reduced by 10% when changing from a rounded to an angular shaped particle (Kaplan 1958). Figure 3 shows the relationship between the particle shape of the aggregate and the workability of the concrete. The strength of concrete also tends to be reduced by increasing aggregate flakiness, with flexural strength being more affected than compressive strength (Kaplan 1959). Flakiness in fine aggregate also affects the properties of fresh concrete mix by increasing the water demand of the concrete mix. This can lead to problems of bleeding and segregation in the fresh mix leading to reduced strength and durability of the resultant hardened concrete (Barker 1983).

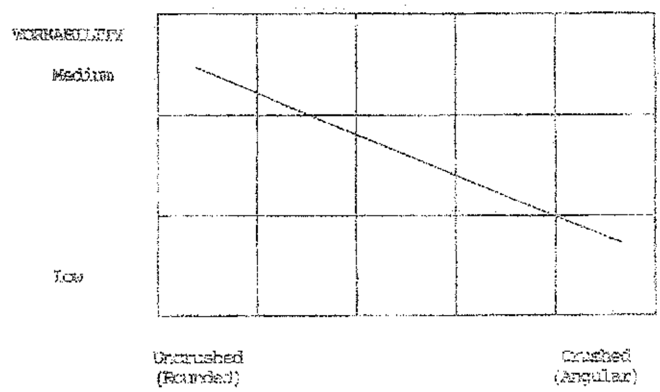

Figure 3. Relation between the particle shape and the workability of concrete [1]

2.5.3 Aggregate Surface Texture

The main influence of particle surface texture is the effect on the bond between the aggregate and the cement paste in hardened concrete. Flexural strength is found to reduce with increasing particle smoothness. However, inadequate surface texture can similarly adversely affect compressive strength in high strength concrete (>60 N/mm2), when the bond with the cement matrix may not be sufficiently strong to enable the maximum strength of the concrete. Recent advances in concrete technology have made it possible to produce very high strength concrete (100N/mm2) with aggregate having a relatively smooth surface texture.

2.5.4 Paste – Aggregate Interface

At the paste–aggregate interface, there is a thin zone vary within 10 and 50μm, called the interfacial zone. It is on the aggregate-matrix interface where crack propagation usually starts under load, leading to gradual failure of the concrete. Since the layer was thin, it contains higher porosity and a higher volume fraction of calcium hydroxide compared to the cement paste away from the aggregate. The zone consumes one-fourth to one-third of the cement paste volume (Garboczi 1995).

The material in this zone has an influence on many properties of the hardened concrete, including strength, elastic properties and permeability. The fluid permeability of concrete is usually higher than of its matrix because of the high permeability in the interfacial zone. A hypothetical explanation of the higher porosity is that at the time of mixing, the aggregate particles become surrounded by a water film several microns thick. When hydration starts, the hydration products combine with this water film. This action leads to the water-cement ratio become higher than the original ratio. (Maso 1980). It has also been shown that the zone frequently contains micro cracks even before loading, and voids from bleeding that can make the concrete weaker.

Lowering the water-cement ratio increases the concrete strength because it makes the materials in the zone become denser and stronger. The same effects of lowering water-cement ratio to the zone can be obtained by including admixtures such as silica fume and superplasticizer. This silica fume will improve the packing of the particles around the aggregates and also consume some of the calcium hydroxide.

2.6 Other Factors Affecting Concrete Strength

Factors that effect concrete strength may be divided into four categories, the constitute materials, methods of preparation, curing procedures, and test conditions. The concrete constitute materials (water, cement, and aggregate) play major roles on affecting the concrete strength and its mechanical properties.

2.6.1 Porosity

The primary factor that governs the strength of brittle materials, like concrete, is porosity. As the capillary porosity decreases compressive strength increases. Also there is data to indicate that large pores may be more effective than small pores in reliving stress concentrations at crack tips. In 1946, Powers and Brownyard published a work that showed that the increase in compressive strength of Portland cement is directly proportional to the increase in gel/space ratio, regardless of age, water cement ratio, or type of cement. The gel/space ratio is the ratio of solid products of hydration to the space available for these hydration products, or a measure of capillary pore space. Before hydration this space is occupied by mixing water, after hydration the space is the sum of the hydrated cement and the remaining capillary pore space. The basic trend of this graph will be the same if different cements or test shapes are used, however, the data points will change. Even thought is this an important quantity the gel/space ratio is difficult to determine.

2.6.2 Water-cement ratio

The effective water-cement ratio is defined as the ratio of the quantity of free water to the quantity of cement in the fresh concrete. Water, absorbed after final compaction, leaves pore spaces behind filled with air in the paste. Thus the strength remains the same as it would be without absorption. Only if such pores are eliminated, the concrete will become stronger corresponding to the reduction in the water-cement ratio.

The capillary porosity of a properly compacted concrete is determined by the water-cement ratio. If concrete is not properly compacted it may contain voids which will contribute to its porosity. At low water-cement ratios where full compaction is difficult to achieve, the relationship between water-cement and strength is invalid. There are some problems associated with using the water-cement ratio as the primary indicator of strength. For example, if finer cements and admixtures are used, 7- and 28-day strengths may not represent the true quality of the cement. However, until some other field test is available, water-cement ratio remains the best indictor of strength and durability.

2.6.3 Cement

Cement affects concrete strength both by its physical and chemical properties. The main factor was the physical of the cement which is the cement size and its texture. In general, a finer material is likely to react more quickly than a coarser material and the same thing goes to cement. Differences in cement particle size, expressed as fineness or surface area, will affect strength development. The fineness to which the cement is ground will evidently affect the rate at which concrete strengths increase after mixing. Grinding the cement more finely will result in a more rapid increase in strength. Fineness is often expressed in terms of total particle surface area, eg: 400 square metres per kilogram.

From the chemical properties, Alite, Alkali and Sulfate causes of strength variability in the concrete. Alite is the most reactive cement mineral that contributes significantly to concrete strength, so a higher Alite content should give better early strengths. Generally, more Alite is good from the viewpoint of early strengths. Large Alite crystals are generally less-reactive than smaller ones.

For particular cement, there will be what is called an 'optimum sulfate content,' or 'optimum gypsum content.' Sulfate in cement, both the clinker sulfate and added gypsum, retards the hydration of the aluminate phase. If there is insufficient sulfate, a flash set may occur; conversely, too much sulfate can cause false-setting. The solubility of the sulfate, and therefore its availability to produce retardation or to cause a false set depends on the starting materials used and the temperature in the cement mill.

A balance is therefore required between the ability of the main clinker minerals, particularly the aluminate phase, to react with sulfates in the early stages after mixing and the ability of the cement to supply the sulfate. The optimum sulfate content will be affected by many factors, including aluminate content, aluminate crystal size, aluminate reactivity, solubilities of the different sources of sulfate, sulfate particle sizes, milling temperatures and whether admixtures are used.If this were not complicated enough, the amount of sulfate necessary to optimize one property, strength for example, may not be the same as that required to optimize other properties such as drying shrinkage. Additionally, concrete and mortar may have different optimum sulfate contents.

It is thought that sulfates affect strength development by influencing the microstructure of the calcium silicate hydrates. Concrete is normally made to a given 'slump' and not to a fixed water-cement ratio. If the sulfate content deviates from the optimum, the workability will be reduced and more water will probably be added to the mix and this could lead to lower the strengths at all ages.

CHAPTER 3

METHODOLOGY

3.1 Gathering and Analyzing Information

Information gathering can be done by researching via the internet and books from the Information Resource Centre, and also by interviewing and consulting lecturers

3.2 Familiarization of the Tools / Equipment

All tools/equipment are available at civil department concrete lab. In the future, if any additional equipment needs to be used, a discussion with the supervisor will be conducted.

3.3 Experimental and Result Analysis

First, the aggregates need to be sieved to get different size of aggregates that is 10, 14 and 20 mm. Sand that being used for mixing also being sieved and the particle distribution curve was plotted. This is to know whether the sand was well graded or not. Figure 4 below shows the aggregates that have been sieved according to the respective required size.

Figure 4. Aggregate that has been sieved and arranged according to the size.

To measure the tensile stress, split tensile test and flexural test were conducted. For split tensile test, three batch of mix were done. Figure 5a and 5b show the machine that being used for the test.

Figure 5a. Flexural and Compression Machine for split tensile test.

Figure 5a. Flexural and Compression Machine for split tensile test.

Each of the mix only uses one particular size of aggregate. The size of aggregate used was 10mm, 14mm and 20mm. 9 cubes of 100 x 100 x 100mm and 3 prism of 100 x 100 x 500mm were used for each mix. The mix proportions for the concrete mix are listed in the table 1, 2 and 3. Detailed design specification can be refer to the appendix A.

Tensile strength using split tensile test was measured by using the cube specimens at 3, 7 and 28 days of strength. For flexural test, the prism was tested at 28 days of strength.

Table 1: Concrete mix proportion for 10 mm aggregate

Material	Weight (kg)
Water	7.9
Cement	15.2
Fine Aggregate	24.51
Coarse Aggregate	33.84

Table 2: Concrete mix proportion for 14 mm aggregate

Material	Weight (kg)
Water	7.48
Cement	14.95
Fine Aggregate	21.55
Coarse Aggregate	33.7

Table 3: Concrete mix proportion for 20 mm aggregate

Material	Weight (kg)
Water	6.84
Cement	13.16
Fine Aggregate	21.3
Coarse Aggregate	41.35

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Split Tensile Test

For split tensile test, 3 specimens for each type of aggregate were used for testing and the average value for stress was calculated. Strength for each type was measured according to 3, 7 and 28 days of strength. Figure 6 shows how the concrete cube was placed in the casing before placed in the testing machine. Table 4, 5, 6 and figure 7 below shows the results for each test.

Figure 6. Placement of the concrete cube in the casing for Split Tensile test.

Table 4. Results of 10 mm size aggregate for split tensile test

Days	3		7		28	
	Max. Load (kN)	Stress (N/mm^2)	Max. Load (kN)	Stress (N/mm^2)	Max. Load (kN)	Stress (N/mm^2)
Cube 1	56.7	3.20	95.6	5.39	156.5	8.83
Cube 2	83.9	4.73	97.3	5.49	150.9	8.51
Cube 3	77.2	4.36	96.1	5.42	144.7	8.16
Average	72.6	4.10	96.3	5.44	150.70	8.50

Table 5. Results of 14 mm size aggregate for split tensile test

Days	3		7		28	
	Max. Load (kN)	Stress (N/mm^2)	Max. Load (kN)	Stress (N/mm^2)	Max. Load (kN)	Stress (N/mm^2)
Cube 1	123.4	6.96	146.2	8.25	196.3	11.08
Cube 2	113.3	6.39	152.5	8.60	193.7	10.93
Average	118.35	6.68	149.4	8.43	195.00	11.00

Table 6. Results of 20 mm size aggregate for split tensile test

Days	3		7		28	
	Max. Load (kN)	Stress (N/mm^2)	Max. Load (kN)	Stress (N/mm^2)	Max. Load (kN)	Stress (N/mm^2)
Cube 1	76.3	4.30	111.3	6.28	171.7	9.69
Cube 2	81.6	4.60	129.7	7.32	185.4	10.46
Cube 3	76.1	4.29	111.2	6.27	193	10.89
Average	78	4.40	117.4	6.62	183.37	10.35

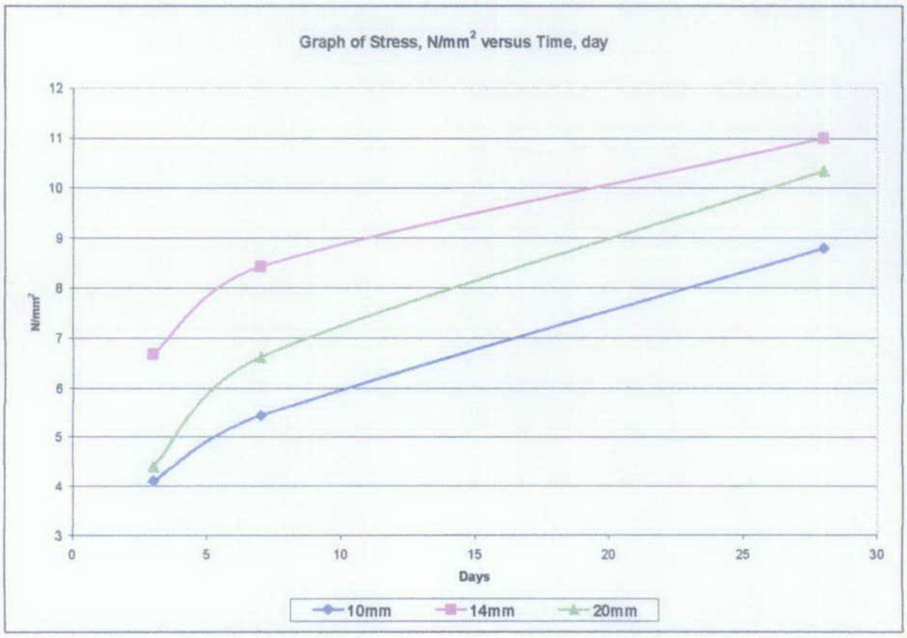

Figure 7. Summary of the results for split tensile test

From the chart, 14mm cube gave the highest stress value (11 N/mm^2), then 20mm (10.35 N/mm^2) and 10mm (8.5 N/mm^2). 20mm cubes gave a slight higher rate of strength development compared to the other sizes up to the first 7 days. After that, the strength development rate was about the same for all of the samples.

According to the theoretical, by reducing the aggregate size, tensile strength of the concrete should be increase. However, if there was too much of surface contact area in the mix, there would be a conflict between the water-cement ratio that being used in the design. The amount of cement paste produced from the hydration process could be not adequate compared to the available contact area. The similar case could occur in the test. The strength given by 14mm aggregate is higher than 10mm aggregate. We could conclude that according to the mix design specification, the maximum stress of the concrete could be achieved by using 14mm size of aggregate. Size of the aggregate does affect the tensile strength of the concrete.

Tensile value obtained from the test could be considered higher compared to ordinary concrete cube (around 10% of the compression strength). While conducting the test, an error in the procedure had occurred. The cube specimen was not placed accordingly in the machine. For the test to yield accurate result, a vertical compressive load is applied, uniformly distributed as a line on two opposing side of the specimen and the contact for the concrete to split need to be one single point. Figure 8 show the correct placement of the cube to conduct the test. Indeed, during the test, the contact point to the cube was only provided on the top side instead of both opposing side. Furthermore, the contact was not a single point. During the test, a steel rectangular bar was used to split the cube when the load applied. Circled area in figure 9 showed the specific bar that being for the test. Instead, we should be using a cylindrical bar or triangle bar that can contact to the cube at only one point.

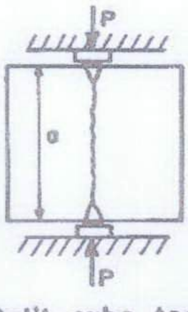

Figure 8. Concrete placement settings for split tensile test.

Figure 9. Rectangular bar being used in split tensile test

4.2 Flexural Test

For flexural test, 3 samples of prism 100x100x500mm were used to test and the test was done at 28 days of the concrete period. Figure 10 show the concrete prism during flexural test. The results for the test were tabulated in 7, 8 and 9. Figure 11 shows the summary for the test. From the results, 14mm aggregate gives the highest flexural strength (8.18 N/mm^2), followed by 10mm aggregate (7.57 N/mm^2) and 20mm aggregates (7.07 N/mm^2).

Figure 10. Concrete prism being test for flexural test

Table 7. Results of 10 mm size aggregate for flexural test

	1	2	3	average
max load (kn)	9.32	10.51	10.44	10.09
max stress (Mpa)	6.99	7.88	7.83	7.57

Table 8. Results of 14 mm size aggregate for flexural test

	1	2	Average
max load (Kn)	12.81	11.27	12.04
max stress (Mpa)	9.6	6.76	8.18

Table 9. Results of 20 mm size aggregate for flexural test

	1	2	3	average
max load (kN)	9.49	9.43	9.35	9.42
max stress (Mpa)	7.12	7.07	7.01	7.07

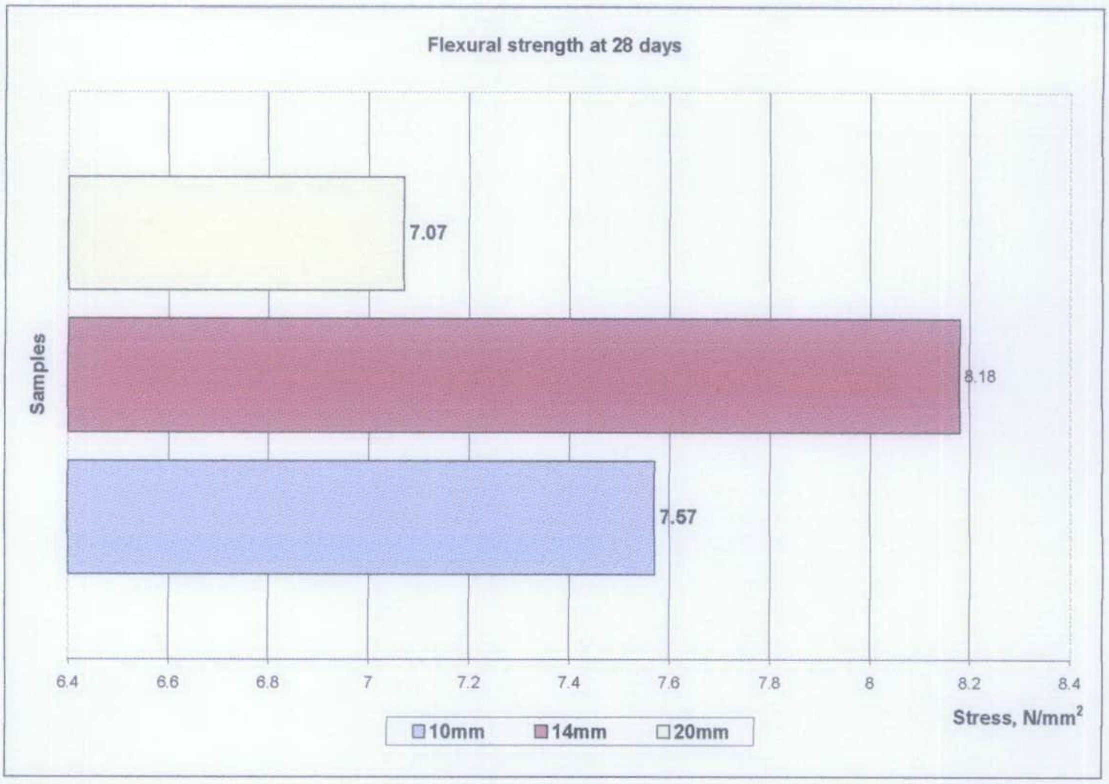

Figure11. Summary of results for flexural test

From the flexural test, the 14mm aggregate yield higher tensile strength than the other aggregates size. This result again shows that 14mm size is the most suitable size of aggregate to be used for that specific design mix in order to achieve the highest tensile strength.

To evaluate these results from the test, free body diagram analysis for the prism can be done. Figure 12 shows the loading condition, shear and moment diagram for the prism similar to the condition when the machine test it.

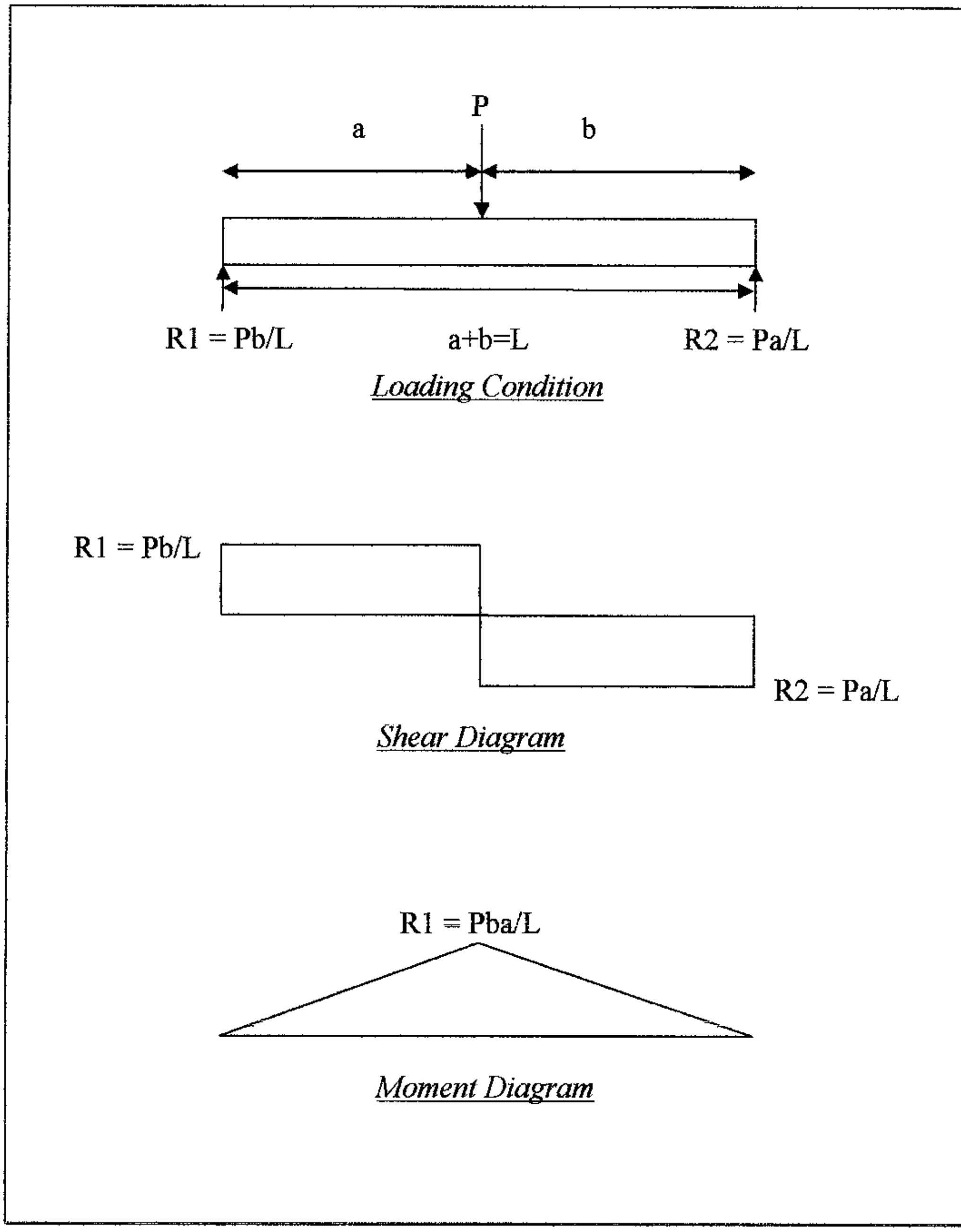

Figure 12. Loading condition, shear diagram and moment diagram

The stress value can be calculated using this equation:

$$\sigma_{\max} = \frac{Mc}{I} = \frac{M}{Z} \text{ and, } Z = \frac{bd^2}{6},$$

Where σ_{max} is the maximum stress value, M is the resisting moment at the section, Z is section of modulus, b the breadth and d is the depth. In this calculation, span length = 400mm and load is applied at the center of the beam. Breadth and depth =

100mm. Recalculating the flexural test result yield the value in table 10, 11 and 12 below.

Table 10. Result of stress value by using free body diagram analysis for 10mm aggregates.

Cube	1	2	3
Max load (kN)	9.32	10.51	10.44
Moment (kN.m)	0.932	1.051	1.044
Section modulus (mm3)	1.67×10^5	1.67×10^5	1.67×10^5
σ, Stress (Mpa)	5.581	6.293	6.251
Stress value from the test (Mpa)	6.99	7.88	7.83

Table 11. Result of stress value by using free body diagram analysis for 14mm aggregates

cube	1	2
max load (kN)	12.81	11.27
Moment (kN.m)	1.281	1.127
Section modulus (mm3)	1.67×10^5	1.67×10^5
σ, Stress (Mpa)	7.671	6.749
Stress value from the test (Mpa)	9.6	6.76

Table 12. Result of stress value by using free body diagram analysis for 20mm aggregates

cube	1	2	3
max load (kN)	9.49	9.43	9.35
Moment (kN.m)	0.949	0.943	0.935
Section modulus (mm^3)	1.67×10^5	1.67×10^5	1.67×10^5
σ, Stress (Mpa)	5.683	5.647	5.599
Stress value from the test (Mpa)	7.12	7.07	7.01

Results from above calculation gives lower value compared to the test. Percentage of different from the test was around 5-15%. Still, the 14mm aggregate give the highest strength compared to the other samples. Flexural strength is an indicator to recognize the tensile strength separately. This recognition is justified because there are major differences between flexural and tensile strength determinations in how the stresses are produced, distributed and calculated [2].

Nevertheless, previous study shows that the splitting strength and flexural strength are usually greater than the direct tensile strength of the concrete. The measured value of tensile strength is reduced more by loading eccentricity and stress peak than is the measured of value of splitting test and flexural test. Relationship between the strength can be refer to the appendix B and appendix C [2].

CHAPTER 5

CONCLUSION AND RECOMMENDATION

By the end this project, we should be able to understand the factors that affecting the concrete strength and how to modify them to achieve specific requirement and how to measure the effects of the modification. Testing the tensile strength can be done by using split tensile test and flexural test. As for the aggregate, we can conclude that aggregate properties do have significant effects to the concrete strength. One of those properties is the aggregate size used in the concrete. By using smaller size of aggregate, the tensile strength of the concrete will increase as the surface area for the cement paste to contact will increase. Other properties also need to be considered when higher tensile strength needs to achieved. Adverse affects of those properties can be minimized if their mechanism is fully understood.

Recommendation on this project would be other factors affecting the strength of concrete also should be experimented and determined in which condition it will reduce or increase the strength. Testing the strength also is a crucial step in doing this kind of project. Other available testing method should be included when measuring the tensile strength. Full understanding of theory and test procedure will result in more accurate result to support our theory.

REFERENCES

1. M.R. Smith and L. Collis. (2001) "Aggregates – Sand gravel and crushed rock aggregates for construction purpose". Published by Geological society.
2. Sandor Popovics (1998) "Strength and Related Properties of Concrete – A Quantitative Approach". Published by John Wiley & Sons, Inc.
3. Louis Primel and Claude Tourenq (2000) "Aggregates". Published by A.A. Balkema/Rotterdam/Brookefield.
4. R.C. Hibbeler (2002) "Structural Analysis" – fifth edition. Published by Prentice Hall.
5. A. M. Neville. (2003) "Properties of Concrete" – fourth edition. Published by Prentice Hall.
6. http://wikipedia.org/
7. www.ScienceDirect.com
8. http://precise.petronas.com.my/search
9. http://hvr.postech.ac.kr/wiki/wiki.php/DeformableObjectRendering

APPENDICES

APPENDIX A	**Calculation for concrete design mix**
APPENDIX B	**Approximation of the relationship between direct tensile and Splitting strengths.**
APPENDIX C	**Approximation of the relationship between direct tensile and Flexural strengths.**

Appendix A

10 mm

Characteristic Strength	:	40 N/mm^2
Slump	:	75 mm
W/C Ratio	:	0.52
Water	:	225 kg/m^3
Cement	:	432 kg/m^3
Total Aggregate	:	1662.3 kg/m^3
Fine Aggregate	:	698.17 kg/m^3
Coarse Aggregate	:	964.13 kg/m^3

12 units of 10 x 10 x 10 cm cubes	:	0.012 m^3
3 units of 10 x 10 x 50 cm cubes	:	0.015 m^3
Total Volume	:	0.027 m^3
Total Volume + 30% wastage	:	0.0351 m^3

Water	:	7.9 kg
Cement	:	15.2 kg
Fine Aggregate	:	24.51 kg
Coarse Aggregate	:	33.84 kg

14 mm

Characteristic Strength	:	40 N/mm^2
Slump	:	75 mm
W/C Ratio	:	0.52
Water	:	213 kg/m^3
Cement	:	426 kg/m^3
Total Aggregate	:	1574 kg/m^3
Fine Aggregate	:	613.86 kg/m^3
Coarse Aggregate	:	960.14 kg/m^3

12 units of 10 x 10 x 10 cm cubes	:	0.012 m^3
3 units of 10 x 10 x 50 cm cubes	:	0.015 m^3
Total Volume	:	0.027 m^3
Total Volume + 30% wastage	:	0.0351 m^3

Water	:	7.48 kg
Cement	:	14.95 kg
Fine Aggregate	:	33.7 kg
Coarse Aggregate	:	21.55 kg

Appendix A

20 mm

Characteristic Strength	:	40 N/mm^2
Slump	:	75 mm
W/C Ratio	:	0.52
Water	:	195 kg/m^3
Cement	:	375 kg/m^3
Total Aggregate	:	1785 kg/m^3
Fine Aggregate	:	606.9 kg/m^3
Coarse Aggregate	:	1178.1 kg/m^3

12 units of 10 x 10 x 10 cm cubes	:	0.012 m^3
3 units of 10 x 10 x 50 cm cubes	:	0.015 m^3
Total Volume	:	0.027 m^3
Total Volume + 30% wastage	:	0.0351 m^3

Water	:	6.84 kg
Cement	:	13.16 kg
Fine Aggregate	:	21.3 kg
Coarse Aggregate	:	41.35 kg

Appendix B

Approximation of the relationship between direct tensile and Splitting strengths

f_t/f_{sp}	Authority[b]	Remarks
[illegible]8	Wright	f_{sp} = 405 psi at the age of 28 days
[illegible]9	Baus and Campus	Cores taken from a 14-year-old concrete beam
[illegible].75	Bonzel	Average based on the findings of several investigators
[illegible]85	Laboratorio Central de Ensayo de Materiales de Construction	f_{sp} = 14.1 kg/cm^2 at the age of 7 days
[illegible]9	Pincus and Gesund	f_{sp} varies from 150 to 450 psi
[illegible].0	Newman	Gravel and crushed stone concretes: maximum particle size is $\frac{3}{4}$ in. f_{sp} varies from 300 to 600 psi
[illegible]28	Newman	Mortar and lightweight concrete; f_{sp} varies from 230 to 500 psi
0.41 to 0.75	Ramesh and Chopra	Cement mortar; f_{sp} varies from 65 to 14 kg/cm^2
0.52 to 0.81	Kadlecek and Spetla	f_{sp} varies from 17 to 28 kg/cm^2
0.55 to 0.93	Campus et al.	Aggregates with different surface textures
0.62 to 0.68	Ledbetter and Thompson	Structural lightweight concrete; f_{sp} varies from 100 to 500 psi
0.69 to 0.96	Ali et al.	Mortars of 1:1 and 1:2 mix proportions; f_{sp} varies from 316 to 618 psi
0.72 to 1.0	Rusch and Hilsdorf	f_{sp} varies from 14 to 33 kg/cm^2
0.86 to 0.94	Malhotra and Zoldners	Maximum particle size is $\frac{3}{8}$ in.
$0.86 + 63/f_{sp}$	Ward	Normal-weight concrete: f_{sp} is in psi
$1.06 - 0.23/f_{sp}$	Komlos	f_{sp} is in MPa; f_{sp} varies from 1.5 to 4 MPa

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[a] 1 ksi = 6.90 MPa; 1 kg/cm^2 = 0.098 MPa.

[b] References for the authors listed in this column can be found in S. Popovics (1967a).

Appendix C

Approximation of the relationship between direct tensile and flexural strengths

f_t/f_{fl}	Authority[b]	Remarks
45	Wright	f_{fl} = 605 psi at the age of 28 days
48	Graf	Wet curing
[illegible]	Hamada	
[illegible]	L'Hermite	
5	Ros	
0.70	Pincus and Gesund	Average value; f_{fl} varies from 200 to 500 psi
744	Raphael	Calculated value supported by experimental data by others
37 to 0.56	Walz	
37 to 0.55	Kadlecek and Spetla	f_{fl} varies from 23.2 to 42.0 kg/cm^2
38 to 0.57	Campus et al.	Aggregates with different surface textures
48 to 0.63	Price	Valid from f_t = 110 to 630 psi
48 to 0.63	Gonnerman and Shuman	Valid from f_{fl} = 230 to 1010 psi
48 to 0.60	Malhotra and Zoldners	Maximum particle size is $\frac{3}{8}$ in.
52 to 0.70	Kaplan	f_{fl} varies from 550 to 850 psi
52 to 0.77	Hummel	
55 to 0.70	Dutron	With different aggregates
0.41 + 0.41/f_{fl}	Komlos	f_{fl} is in MPa; f_{fl} varies from 2.7 to 9.3 MPa
0.63 + 61/f_{fl}	Ward	f_{fl} is in psi; for normal-weight and lightweight structural concretes

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[a] ksi = 6.90 MPa; 1 kg/cm^2 = 0.098.

[b] References for the authors listed in this column can be found in S. Popovics (1967a).