Mechanical behaviour of fibre reinforced concrete using soft–
drink can

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Abstract. This research was carried out to study the behaviour of concrete, specifically compressive and flexural strength, by incorporating recycled soft drink aluminium can as fibre reinforcement in the concrete. Another aim of the research is to determine the maximum proportion of fibres to be added in the concrete. By following standard mix design, Ordinary Portland Cement (OPC) concrete was made to have a target mean strength of 30 N/mm\(^2\) with not more than 30 mm of slump. Having the same workability, OPC concrete with 0%, 1% and 2% of soft drink can aluminium fibre was prepared based on weight of cement. The specimens were tested for compressive strength and flexural strength. Laboratory test results based on short term investigation reveals that the compressive strength and flexural strength of concrete containing fibre are higher than of normal OPC concrete. Among two volume fractions, concrete with 1% of soft drink can fibre have performed better result in compressive strength and flexural strength compared with 2% amount of soft drink can fibre. The optimum proportion of aluminium fibre to be added in the concrete as fibre reinforcement is 1% fibre content by weight of cement which gave all the positive response from all the tests conducted.

1. Introduction

These concrete is a Portland cement concrete when the aggregate is mixed together with dry cement and water, they form a liquid mass that is easily to mould in shape. Concrete is the most widely used construction material due to its high compressive strength, long service life and low cost. However, concrete is relatively strong in compression but weak in tension and low crack resistance. To improve such weakness of the concrete, fibre reinforced concrete have been developed. Fibre reinforced concrete has already found wide range of practical application and has proved as a reliable construction material that having good performance characteristic compared to conventional concrete [1]. Fibres in the concrete commonly are produced from a large variety of materials like steel, glass, organic, polyester and other materials various shapes and sizes. Considering the waste management system and global energy crisis, there are many research work have been carried out in recent years on waste materials to determine the characteristics and advantages [2]. Therefore, this research study about one of the potential recycled materials which is aluminium soft drink can.

Considering the availability and environmental issues in term of waste management, a research was conducted to study the effect of aluminium soft drink can as fibre reinforcement in concrete construction. Standard concrete specimens were cast with different percentage of fibre based on
weight of cement and tested for density and strength. The mechanical properties of the specimens were tested with experimental tests such as compressive strength test and flexural strength test.

1.1. Problem statement
To overcome some disadvantages of concrete such as having relatively low tensile strength (compared to other building materials), low ductility, low strength-to-weight ratio and susceptible cracking, it is essential to find alternatives to improve the qualities of concrete. The use of fibre reinforcement is applied to concrete as fibre reinforced concrete. The application of fibre in concrete does not only change the properties of normal concrete but also will have some good improvement for the performance of concrete in building construction.

Recycling various kinds of waste materials undoubtedly will be the one of the problems that will most afflict the society in the future and that we must address and resolve in all possible ways. It is necessary that researchers find solutions that are original, imaginative and brilliant to reuse the waste. With the scarcity of space for landfilling and due to an ever increasing cost, the attention is towards the reuse of waste as an alternative to disposal. Research is always more interested in the use of such products in the concrete mix. This makes the concrete more economic and, at the same time, there is a reduction of problems regarding waste materials. For this research, by using waste material specifically aluminium soft drink cans as the fibre reinforcement material, it not only can decrease the number of dumping waste but also can strengthen the concrete in low cost.

1.2. Scope of study
Please In this research, the mechanical properties of fibre reinforced concrete that containing soft drink cans aluminium fibre were studied. Important properties such as compressive strength and flexural strength were the main focus. To understand the development of fibre reinforced concrete adding aluminium fibre, few tests were conducted. The test conducted was at fresh state and hardened state. Slump test was conducted at fresh state of concrete mix to ensure the workability of concrete and also meets the required slump height in the range between 10mm to 30mm as followed concrete mix design. At hardened state, compressive strength test was conducted on the cubes and cylinder specimens. The cube specimens were 100mm x 100mm x 100mm size and cylinder specimens were 150mm x 300mm. Both types of specimens were cured with water curing method. The ages of curing for cubes were 7 days and 28 days respectively. Cylinder specimens were cured for 14 days. For flexural test, rectangular beam specimens with 100mm x 100mm x 500mm were tested on the age of 14 days cured and also wet-cured.

To determine the maximum proportion of the fibre that can be added into the concrete, the percentage of fibre based on weight of cement was the variable for this research. Concrete with 1% and 2% fibre content were used to determine the effect of fibre reinforced concrete with different amount of fibre.

2. Literature review
The Concrete is a typical construction material that is commonly used due to its several advantages such as high concrete strength. High concrete strength can be produced by fulfilling the requirement of construction demand. However, concrete is relatively strong in compression but weak in tension and quite brittle [3].

The weakness of concrete can be overcome by the use of steel bars reinforcement or mixing with a sufficient amount of fibres. Fibres varying from size, material and geometry have been added into the concrete can produce a better construction material called Fibre Reinforced Concrete (FRC). Fibres added to the concrete are generally measured with the portion of total volume of concrete and known as volume fraction. The use of fibres also recalibrates the behaviour of the fibre-matrix composite after it has cracked through improving its toughness [4].

Solid waste is a major environmental problem in Malaysia and is significantly reducing our environment capacity to sustain life. There have been increasing construction wastes attributable from
insufficient waste management practices in the construction projects since the last two decades [5]. The amount of waste generated continues to increase due to the increasing population and development and only small percentage of waste is being recycled. Most of the wastes which can be recycled include glass, paper, plastic and aluminium. There are many researches done by using waste material as fibre in the concrete. The investigation that have been made shows that the behaviour of fibre concrete by using the waste material such as lathe waste, soft drink bottle caps and beverage tin wastes and found that the strength of concrete for all the fibre has been increased significantly than ordinary concrete [6]. Besides, a research was conducted using recycled waste PET (polyethylene terephthalate) bottles fibres for the reinforcement of concrete. The results tested on concrete reinforced with circular PET fibres and long strips shows fibres give more ductile behaviour of concrete and a high concrete-PET adherence [7]. Therefore, this research study about one of the potential recycled materials which is aluminium soft drink can.

3. Methodology
To study the behaviour and characteristic of fibre reinforced concrete with aluminium fibre, the laboratory testing conducted were compressive strength test and flexural strength test.

3.1. Material
The material used for this concrete is ordinary Portland cement (OPC), sand, aggregate and tap water. The ratio of concrete mix is 1:1:2 which are for cement, sand and aggregate respectively. The size of sand is according the 600μm sieve by passing 70% and the size of aggregate is 10 to 20mm. The concrete was design to be grade 20. For the preparation of soft drink can aluminium fibre, soft drink aluminium can were collected and cleaned. The top and bottom of the can is then cut off to obtain aluminium sheets. Then the sheets are cut into strips and finally the strips are cut into fibre form with constant dimension.

3.2. Concrete design mix
The purpose of concrete mix design is to ensure the most optimum proportions of the constituent materials to fulfil the requirements. Table 1 shows the constituent material composition for the design mix.

| Material                  | Composition |
|---------------------------|-------------|
| Cementitious materials    | 380 kg/m³   |
| Fine Aggregate            | 549 kg/m³   |
| Coarse Aggregate          | 1281 kg/m³  |
| Water-cement ratio (by mass) | 0.5        |
| Fine-coarse aggregate ratio (by mass) | 1:2       |

4. Result and discussion

4.1. Density of specimens
As shown in table 2 below, the density of the cube specimens for all fibre content increased from 7 days to 28 days. The result shows that for each types of specimens, concrete with 1% fibre have the highest density compared to others. On the other hand, concrete with 2% fibre have the lowest density. This is because excess amount of fibre may affect the moisture content or hydration of concrete during curing process so that the weight of concrete after cured become lighter compared to others. From the data obtained, this can be concluded that fibre content can affect the density of the concrete.
Table 2. Density of specimens.

| Type of Specimens | Fiber Content | 7 days (kg/m³) | 28 days (kg/m³) | 14 days (kg/m³) |
|-------------------|--------------|----------------|-----------------|-----------------|
| Cube              | Normal       | 2409           | 2412            | -               |
|                   | 1%           | 2443           | 2450            | -               |
|                   | 2%           | 2377           | 2394            | -               |
|                   | Average      | 2409.67        | 2418.67         | -               |
| Cylinder          | Normal       | -              | 2346.53         | -               |
|                   | 1%           | -              | 2351.82         | -               |
|                   | 2%           | -              | 2338.99         | -               |
|                   | Average      | -              | 2345.78         | -               |
| Rectangular Beam  | Normal       | -              | -               | 2426.78         |
|                   | 1%           | -              | -               | 2456.00         |
|                   | 2%           | -              | -               | 2391.80         |
|                   | Average      | -              | -               | 2424.86         |

4.2. Compressive strength test

Referring to the table 3 below, the compressive strength increased corresponding with the age of curing. Specimens with no fibre content have the increasing strength from 18.59 N/mm² to 25.80 N/mm². For 1% fibre content of specimens, the strength increase from 21.36 N/mm² to 29.072 N/mm². Then, 2% fibre content of specimens also showed an increasing strength value from 18.13 N/mm² to 23.093 N/mm². The mixes also exceed the design grade of 25 and shows good compressive strength. The result show the increment of strength from curing period 7 days till 28 days because the specimens gain strength over the time during water curing in curing tank. The curing process is to maintaining the moisture level inside cast concrete, as long as free moisture exists inside the concrete, the strength, hardness and density increase gradually [8].

The addition of aluminium fibre among two different percentage of fibre had shown different effect on the specimens compared to the normal concrete. Concrete with 1% fibre shown increased strength compared to the normal concrete and had the highest strength among all the specimens. However, concrete with 2% fibre shown negative influence and had the lowest strength among all the specimens. The negative response in strength gain of concrete with 2% fibre is because the loss of bond inside the specimens due to excess amount of fibre.

It can be concluded that maximum or suitable proportion of fibre that can be added as improve the strength of concrete is 1% of fibre content by weight of cement.

Table 3. Compressive strength result

| Type of Specimen | Fiber Content | Day | Compressive Strength (N/mm²) |
|------------------|--------------|-----|-------------------------------|
| Cube             | Normal       | 7   | 18.59                         |
|                  | 1%           |     | 21.36                         |
|                  | 2%           |     | 18.13                         |
|                  | Normal       | 28  | 25.80                         |
|                  | 1%           |     | 29.072                        |
|                  | 2%           |     | 23.093                        |
| Cylinder         | Normal       | 28  | 18.84                         |
|                  | 1%           |     | 22.00                         |
|                  | 2%           |     | 11.75                         |
4.3. Flexural strength test
The flexural strength of normal concrete and fibre reinforced concrete were tested at the curing age of 14 days with rectangular beam specimens [9]. Table 4 show the result of flexural strength test. The results show an increasing value of flexural strength with the increasing amount of fibre in the specimens. The normal concrete has the value of 0.922 N/mm². However, when the strength reach the highest value at specimen with 1% of fibre which is 1.003 N/mm², the value decrease significantly at the 2% of fibre specimen with the value of 0.224 N/mm². These result shown that the increase in strength only up to 1% fibre content but decrease when the amount of fibre increased. Specimens with excess amount of fibre cannot carry more load because the cause of congestion of fibre. The congestion of fibre may cause the bonding of concrete become weak and the concrete system will become disintegration.

Table 4. Flexural strength of rectangular beam specimens.

| Type of Specimen | Fibre Content | Day | Modulus of Rupture (N/mm²) |
|------------------|---------------|-----|----------------------------|
| Rectangular Beam | Normal        | 14  | 0.922                      |
|                  | 1%            |     | 1.003                      |
|                  | 2%            |     | 0.224                      |

5. Conclusion
The values compressive strength increase with the increase amount of fibre in the concrete mix [10]. However, there are limits to which the excess amount of fibre will cause the strength to decrease. Therefore, it shows that if the fibre content higher it affects the strength of the concrete [11]. The negative response that concrete with 2% fibre have the least strength is because loss of bonding due to excess amount of fibre. Overall, the optimum percentage to obtain the highest compressive strength is 1%.

For flexural strength test, similar trend of results was observed when comparing to the compressive strength test. The strength increase when 1% fibre was added into the concrete but decrease in strength with the percentage of 2% fibre added into the concrete. This shows that increase in strength is only up to certain percentage of fibre content. It also can be deducted that specimens with higher amount of fibre cannot carry extra load due to congestion of fibre. The congestion of fibre may cause the bonding of concrete become weak and the concrete system will become disintegration.

The amount of fibre is corresponding to the density and strength of concrete was observed from each type of specimens. The highest density and strength is from concrete with 1% of fibre content. As the density is increased, the strength of concrete also increased. Concrete with 2% of fibre have the lowest density due to excess amount of fibre that may affect the moisture content or hydration of concrete during curing process so that the weight of concrete after cured become lighter compared to others.

From all the result, it can be concluded that maximum proportion of fibre to be added into concrete as fibre reinforced concrete is 1% fibre content by weight of cement which gave all the positive response from all the tests conducted.

6. References
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