Effect of nylon fiber on mechanical properties of cement based mortar

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Abstract. An investigation has been carried out to study the effect of nylon fiber on the mechanical properties of cement based mortar after receiving large quantities of nylon waste. Subsequently, this research was conducted to compare the compressive, tensile and flexural strength of normal cement based mortar with nylon fiber cement based mortar. All samples using constant water-cement ratio of 0.63 and three different percentages of nylon fiber were added in the mixture during the samples preparation period which consists of 0.5%, 1.5% and 2.5% by total weight of cement based mortar. The results obtained with different nylon percentage marked an increases in compressive strength (up to 17%), tensile strength (up to 21%) and flexural strength (up to 13%) when compared with control cement based mortar samples. Therefore, the results obtained from this study shows that by using nylon fiber as additive material can improve the mechanical properties of the cement based mortar and at the same time produce a good sustainable product that can protects and conserve the marine environment.

1. Introduction
According to Duggal [1], mortar has been selected as building materials because of it special properties such as producing a strong bond between the mortars and stone and its whether and chemical resistant makes it long lasting and suitable as a building material. Thus, the quality improvement of mortar continues till today. In addition, the performance of mortar was improved by inclusion of fiber and was very popular as a method to enhance the strength. Fiber has several of types such as glass, carbon, plastic and nylon. The special characteristic of nylon is strong, elastic and fast drying [2]. Unfortunately, lot of waste nylon net were been dumped in the sea and it was reported that one of the whale's internal organs had ruptured abdominal area caused by the nylon net that was stuck in the whale stomach [3]. Hence, utilizing of waste nylon or nylon fiber as an additive in mortar will reduce the pollution and protect the marine environment. Habib et al. [4] prove that with additive of 2% of nylon fiber in cement based mortar shows higher compressive strength by 42.8% compared with normal cement based mortar. The compressive strength of 1.5% nylon fiber cement based mortar with 1.0 inch length was 36.3 MPa, while the compressive strength of 1.5% nylon fiber cement based mortar with 1.5 inch length was 39.6 MPa. This results shows that the length of nylon fiber affects the compressive strength of cement based mortar. The addition of shorter length of nylon fibers causes a decrease in the compressive strength of cement based mortar. The performance of the mortar can be improved with utilization of higher percentage and longer length of nylon fiber [5]. By adding higher percentage of nylon fiber up to 2%, the tensile and flexural strength of cement based mortar can be increase. This is because by adding fiber in cement based mortar, the plasticity of cement based mortar will increase thus delaying the formation of the cracks in the cement based mortar when load are applied[4]. The effect of using nylon fiber in cement based mortar should be carried out further in laboratory to gather additional prove regarding the effectiveness of nylon fiber in mortar in term of
compressive strength, tensile and flexural strength. The addition of nylon fiber in the cement based mortar can improve the durability and mechanical properties of ordinary mortar [4]. Henceforth, the effect of cracking also can be improved [6].

2. Materials
Nylon fiber (figure 1) was used in this research. The fiber was collected from TCE Tackles Sdn Bhd, Lunas, Kedah and was prepared manually by cutting 0.33 mm diameter fishing line fiber into 1.5 inch length. The Ordinary Portland Cement (Tasek Cement) was used throughout this research. Meanwhile, river sand was collected from the nearest local river and was oven dried for 24 hours with 110°C. Constant water-cement ratio of 0.63 was used for all samples and three different percentages of nylon fiber were added in the cement based mortar consists of 0.5%, 1.5% and 2.5% by total weight of cement based mortar.

![Figure 1. Nylon fiber.](image)

3. Methodology
The compressive, tensile and flexural strength of nylon fiber cement based mortar were determined using BS EN 12390-3:2009 [7], BS EN 12390-6:2009 [8] and BS EN 1015-11:1999 [9]. Mortar mix design ratio of 1:3 was used in this research. Mortar mixture was prepared by mixing cement and sand. Then, water was added with constant water cement ratio of 0.63. When mortar mixture becomes uniformly mix, nylon fibers was added slowly to prevent bounding of the fibers. Cubical samples of 100 mm x 100 mm x 100mm, cylindrical samples of 150 mm diameter with 300 mm height and beam samples of 350 mm x 75 mm x 75 mm were prepared based on the mortar mix design. All the samples were stored under normal water at room temperature for 7 and 28 days for curing. Cubical and cylindrical samples were tested by compression machine while beam samples were tested using universal testing machine. Figure 2 shows the flexural test set-up with specimen dimension.
4. Results and discussions

4.1. Effect of nylon fiber on the compressive strength of cement based mortar

The compressive strength results were presented in figure 3.

Figure 3. Compressive strength of cement based mortar with different percentage of nylon fiber.

Figure 3 showed that 0.5 % nylon fiber cement based mortar has the highest compressive strength compared to control cement based mortar and others nylon fiber cement based mortar. The compressive strength of 0.5% cement based mortar at the age of 7 and 28 days is 28.8 MPa and 37.3 MPa meanwhile the compressive strength of control cement based mortar at the age of 7 and 28 days is 23.8 MPa and 31.4 MPa. Hence, 0.5% nylon fiber cement mortar has higher compressive strength compared to control cement based mortar by 21% and 19% at 7 and 28 days of age. On the other hand, 1.5% and 2.5 % nylon fiber cement based mortar showed a reduction in the compressive strength compared to control cement based mortar by 7-30%. According to Spada et al. [5] and Campello et al. [10] by adding more nylon fibre will created higher porosity or cavity between the
mortar matrixes which causes compressive strength of cement based mortar to decrease. Another factor affecting the compressive strength of cement based mortar is the water-cement ratio. Additional of water in the mix mortar will produce higher porosity in hardened cement based mortar and led to lower compressive strength [11].

4.2. Effect of nylon fiber on the tensile strength of cement based mortar

The tensile strength results were presented in figure 4.

![Figure 4. Tensile strength of cement based mortar with different percentage of nylon fiber.](image)

Figure 4 showed that 0.5 % nylon fiber cement based mortar has the highest tensile strength compared to control cement based mortar and others nylon fiber cement based mortar. The tensile strength of 0.5% cement based mortar at the age of 7 and 28 days is 2.95 MPa and 3.09 MPa meanwhile the tensile strength of control cement based mortar at the age of 7 and 28 days is 2.32 MPa and 2.75 MPa. Hence, 0.5% nylon fiber cement mortar has higher tensile strength compared to control cement based mortar by 27% and 12% at 7 and 28 days of age. On the other hand, 1.5% and 2.5% nylon fiber cement based mortar showed a reduction in the tensile strength compared to control cement based mortar by 9-28%. Previous studies by Orasutthikul et al. [12] demonstrated that increase of length and quantity of nylon fibers causes a decrease in tensile strength of mortar and high water-cement ratio will contributed to the reduction of the tensile strength of mortar [11].

4.3. Effect of nylon fiber on the flexural strength of cement based mortar

The flexural strength results were presented in figure 5.
Based on figure 5, by adding more nylon fiber up to 2.5% in cement based mortar increases the flexural strength of cement based mortar. 1.5% and 2.5% nylon fibers cement based mortar have higher flexural strength by 1% - 13% at the age of 7 and 28 days compared to control cement based mortar. Meanwhile 0.5% nylon fiber cement based mortar showed slight reduction of flexural strength compared to control cement based mortar by 6% - 7%.

Figure 6. Load vs deflection of cement based mortar with different percentage of nylon fiber (7 days).

Figure 6 above shows the results of the maximum load and deflection of control and nylon fibers cement based mortar samples at the age of 7 days. 2.5% nylon fiber cement based mortar beam able to bear maximum load of 9.68 kN. Meanwhile, 1.5%, 0.5% nylon fiber and control cement based mortar beams able to bear maximum load of 8.75 kN, 8.06 kN and 8.60 kN. Higher deflection represents higher lifespan for the tested beam. Based on figure 6, 2.5% nylon fiber cement based mortar has the
highest beam deflection value with 1.64 mm, followed by 1.5 %, 0.5 % nylon fiber and control cement based mortar with 1.44 mm, 1.24 mm and 0.76 mm.

**Figure 7.** Load vs deflection of cement based mortar with different percentage of nylon fiber (28 days).

According to Spadea et al. [5], the utilization of longer length and higher percentage of nylon fiber in cement based mortar causes the specimens able to bear higher load and able to extend the specimens lifespan. Additional percentage of nylon fiber will increase the plasticity of the mortar thus delaying the process of cracking and enhance the flexural strength of mortar [4]. De Oliveira and Castro-Gomes [13] stated that nylon fibers can increase the bending load to withstand the specimen...
capacity, especially at the stage after a failure occurs. Based on figure 6,7 and 8, the control cement based mortar beam was completely broken when subjected to the maximum load while nylon fiber cement based mortar beams did not fully broken as a result of bonding of nylon fibers with mortar.

5. Conclusion
The results showed a positive effect on the compressive and tensile strength of cement based mortar by utilizing 0.5% nylon fiber. By using higher quantity of nylon fiber, the compressive and tensile strength of cement based mortar decreases. Adding more water and percentage of nylon fiber in cement based mortar creates the development of higher porosity between mortars thus causing cement based mortar compressive strength to decrease. Utilizing nylon fiber in cement based mortar can increase the load capacity, especially at the stage after the failure occurred and also increase the plasticity of the mortar hence delaying the process of cracking and improved on the flexural strength of mortar. Overall, the addition of 0.5% of nylon fiber in the mortar mix able to enhance the compressive strength, tensile strength and flexural strength. Furthermore, the use of nylon fiber in the mortar can create a sustainable cement mortar and provide a good change to the environment by reusing the waste material thereby reducing pollution.

6. References
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