The Study of Kenaf Powder Performance in Mortar

S S Ayop\textsuperscript{1,2}, S Rasli\textsuperscript{1}, S N Moharam\textsuperscript{1}, M S Wahab\textsuperscript{3} and N Sa’ude\textsuperscript{3}

\textsuperscript{1}Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, Malaysia
\textsuperscript{2}Jamilus Research Centre, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Johor, 86400, Malaysia
\textsuperscript{3}Faculty of Mechanical Engineering and Manufacturing, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, Malaysia

Corresponding author: sallehs@uthm.edu.my

Abstract. As cement is essential in producing mortar, reforms and innovations are needed to reduce the adverse effects of CO\textsubscript{2} in the future. The objectives of this study were to determine the optimal amount of kenaf powder in mortar strength and to examine the mechanical and flexural properties of kenaf powder in the mortar. Thirty-six mortar cubes of 50 mm x 50 mm x 50 mm and 12 number of mortar prism were cast using mix ratio of 1:3 with two different water-cement ratios. The replacement of kenaf powder ranging from 10\% to 20\% to the cement matrix were tested to investigate the mechanical parameters such as workability, density, compressive strength, and water absorption capabilities. Furthermore flexural strength was assessed using a similar mix proportion. The mortar containing 10\% of kenaf powder and superplasticizer additives had demonstrated the best performance in workability and improved the compressive strength and flexural strength.

1. Introduction

Every tons of Portland cement produced, about one tons of CO\textsubscript{2} is released into the environment. The cement sector is, in fact, responsible for around 7\% of worldwide CO\textsubscript{2} emissions. Research on this issue is starting to be carried out on potential materials for the use of cement in mortar, as not only society but also the environment are adversely affected by carbon dioxide emitted from cement. In order to overcome this problem and because of its easy growth and abundant availability in Malaysia, kenaf is a more promising green-based adsorbent utilized to replace commercial adsorbents [1]. Many studies on mechanical properties of kenaf powder are needed to gain environmental benefits without compromising mortar performance.

In Malaysia, mortar is widely used for wall plastering and brick binding. Mortar is a combination of cement, fine aggregates, and water used to improve the aesthetic value of a building and the sound and water-resistance of the wall construction [2]. However, mortar is not as effective as concrete and is usually not used as a single construction material [3]. Therefore, to improve the mechanical properties of the mortar, various forms of replacement and additional materials have been developed. Though the growth of the construction industry in this country, multiple studies that contribute to the efficiency and quality of construction have been done.

The objectives of this study were, to investigate the mechanical properties of mortar containing kenaf powder; to determine the optimum content of kenaf powder in the mortar strength and to study the effects of kenaf powder in flexural strength.
2. Sample Preparation and Testing

In this project, a total of 36 mortar cubes size 50 mm x 50 mm were used to determine the compressive strength on 7 and 28 days and 12 prisms size 40 mm x 40 mm x 160 mm were used to determine the flexural strength.

2.1. Materials

Preparation of sampling materials has been undertaken to ensure that the samples comply with the appropriate requirements. Several of the materials used were Ordinary Portland Cement (OPC), untreated kenaf powder, superplasticizer and fine aggregate. OPC used in this research was manufactured in compliance with the quality standards set out in the Malaysia Standard, MS 522:1:1989 OPC Specifications. Subsequently, the material passed the sieve analysis test to find the proportion of kenaf powder smaller than cement. The scale of the kenaf powder granules with the full size is physically identical to the cement’s size. The fine aggregate gradation was finer than 5.0 mm. In this experiment, the superplasticizer (SP) used is Estop Admix AP. The water used in the mix was free from organic matter, chloride, acidic substances and silt and safe to drink in order to produce a good mortar mix. Table 1 shows the mix proportion used in this study. Kenaf powder was used as a cement replacement materials ranging from 10% to 20% by cement volume. Two w/c ratios were used were 0.4 and 0.5, while SP was used to check the workability effects on the mortar mix. From total 36 number of cube specimens, 27 specimens containing kenaf powder and 9 samples were used as a reference. The workability of the fresh mortar mix was examined according to BS EN 1015-3:1999.

Table 1. The mix proportion of 1:3 (cement: sand) for single mortar.

| Mix Designation | Sand (kg) | Cement (kg) | Kenaf Powder (%) | Water (kg) | w/c |
|-----------------|-----------|-------------|------------------|------------|-----|
| Control         | M11       | 0.114       | 0.034            | 0.014      | 0.4 |
|                 | M12       |             | 0.034            | 0.014      | 0.4 + SP |
|                 | M13       |             | 0.017            |            | 0.5 |
| KP 10%          | M21       | 0.114       | 0.031            | 0.012      | 0.4 |
|                 | M22       |             |                  | 0.012      | 0.4 + SP |
|                 | M23       |             |                  | 0.015      | 0.5 |
| KP 15%          | M31       | 0.114       | 0.029            | 0.011      | 0.4 |
|                 | M32       |             |                  | 0.011      | 0.4 + SP |
|                 | M33       |             |                  | 0.014      | 0.5 |
| KP 20%          | M41       | 0.114       | 0.027            | 0.011      | 0.4 |
|                 | M42       |             |                  | 0.011      | 0.4 + SP |
|                 | M43       |             |                  | 0.014      | 0.5 |

For hardened mortar samples as in figure 1, the density test was conducted to study the effects of kenaf powder replacement on dry density of mortar. Water absorption test was conducted to examine the effects of kenaf particles when exposed with water. The strength characteristic of the mix was assessed based on the compressive strength on 28 days after cast. Furthermore, flexural strength test was conducted to assess the Modulus of Rupture of the prism.
3. Results and discussion
The results from the laboratory tests on the mortar specimen has been analysed and discussed accordingly.

3.1. Slump flow test
As shown in figure 2, for a similar mix proportion, the flow of the wet mortar was increased with an increasing of w/c ratio ranges from 22% on the control specimen up to 28% on the specimen with 20% kenaf powder. The additional of SP in the mix had improved the flow of the mortar. However the present of the kenaf powder had reduced the flow significantly when compared with the control samples. Kenaf powder is polar and it contains hydroxyl groups that have the capability to bind with the water molecules via hydrogen bonding during immersion [4]. Therefore it had reduced the free water content of the mortar mix thus reduce the ability of the materials to flow. The trend in figure 3 had proved this assumption. As can be seen, a linear increment of water absorption was observed on the sample with the increment of kenaf powder content.

![Figure 1. Cube and prism samples.](image1)

![Figure 2. Flow test result for different w/c ratios.](image2)
3.2. Compressive strength

Figure 4 shows the result of compressive strength on 28 days after cast. The replacement of 10% kenaf powder in the cement content had shown its effects in enhancing the compressive strength up to 5% regardless its w/c ratio when compared with control specimen. However, this trend reduced steadily with the increment of kenaf powder replacement. Opposite trend was observed in Zhou et al. [5] study when they used kenaf fiber with 5 to 15 mm length in high strength cement composite study. The fiber only effective in enhancing the flexural strength but not in the compressive strength.

For 0.4 w/c ratio, the additive that used in the mix had significantly improved the compressive strength. The higher changes were observed on 10% kenaf replacement with the increment of 16%. Furthermore, higher compressive strength was found on the mix with SP regardless the kenaf powder content. Therefore, besides workability, SP had works significantly in increasing the compressive strength of the mortar.

Higher compressive strength was observed on 0.5 compared to 0.4 w/c ratio. The lower of water content in the 0.4 w/c ratio mix had affected the mixing process where the mix became dry and difficult to compact. It can be seen in the density test results of the samples in table 2 where the density of the 0.5 w/c was higher than 0.4 w/c.
Figure 4. Mortar compressive strength at 28 days.

Table 2. Density test of mortar cube.

| Mix Designation | Average Density for 28 Days (kg/m³) |
|-----------------|-----------------------------------|
| Control         |                                   |
| M11             | 2156                              |
| M12             | 2175                              |
| M13             | 2163                              |
| KP 10%          |                                   |
| M21             | 2169                              |
| M22             | 2184                              |
| M23             | 2177                              |
| KP 15%          |                                   |
| M31             | 2142                              |
| M32             | 2158                              |
| M33             | 2155                              |
| KP 20%          |                                   |
| M41             | 2120                              |
| M42             | 2137                              |
| M43             | 2133                              |

3.3. Flexural strength

3-point bending test was conducted on the prism sample and the modulus of rapture (σ) was calculated accordingly using the following equation (1):

\[ \sigma = \frac{3FL}{2bd^2} \]  

where, \( F \) is a force at crack point, \( L \) is a support span, \( b \) is width and \( d \) is depth of the prism. The span was set at 120 mm and the summary of the flexural test is depicted in figure 5. Flexural strength was higher on specimen with 10% kenaf powder replacement. By adding superplasticizer in the mix have improved the flexural strength of the mortar sample when compared with sample without superplasticizer.
4. Conclusion
Based on the result from the experimental works done, it shown that kenaf powder can be used as a cement replacement in the mortar. 10% of kenaf powder replacement in the mix had improved the compressive strength and the flexural strength of the mortar prism. Furthermore, the absorption rate of the mix was higher when compared to the control specimens, and the trend of increment was observed when the percentage of replacements were increased. It is worth to mention that the superplasticizer used in this study plays an important role in enhancing the workability, compressive strength and flexural strength of the mortar mix.

5. References

[1] Bamigboye G O, Davies I, Nwanko C, Michaels T, Adeyemi G and Ozuor O 2019 Innovation in Construction Materials- A Review IOP Conf. Ser. Mater. Sci. Eng. 640 012070
[2] Tam M T and Weng C C 1994 A study on acoustic emission characteristics of fly ash cement mortar under compression Cem. Concrr. Res., 24 1335–1346
[3] Ahmadi Z, Esmaeili J, Kasaei J and Hajialioghli R 2018 Properties of sustainable cement mortars containing high volume of raw diatomite, Sustain. Mater. Technol. 16 47–53
[4] Alias N F, Ismail H and Ku Ishak K M 2019 The effects of kenaf loading on water absorption and impact properties of polylactic acid/ natural rubber/ kenaf core powder biocomposite Materials Today: Proceedings 17 584-589
[5] Zhou C, Cai L, Chen Z and Li J 2020 Effect of kenaf fiber on mechanical properties of high-strength cement composites, Construction and Building Materials 263 121007

Acknowledgements
The authors would also like to thank the Material Engineering Laboratory and Advanced Materials Engineering Laboratory, Faculty Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for their facilities support.