Recent Trends in Civil Engineering and Built Environment Vol. 4 No. 3 (2023) 137-143

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

A Review: The Effects of Marble Dust on Mechanical Properties and Structural Behavior of Concrete

Nurul Atikah Heshammuddin[1], **Goh Wan Inn**[2]

[1,2]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Senior Lecturer, Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia

DOI: https://doi.org/10.30880/rtcebe.2023.04.03.015
Received 06 January 2022; Accepted 15 May 2023; Available online 31 December 2023

Abstract: Marble dusts were produced by the cutting process of metamorphic rocks that frequently used for a sculpture and as a building material. Instead of the good environmental management for marble dust, it is often dumped into an open field. Recent research development has shown that marble dust able to be utilized in concrete as a cement replacement material. By replacing marble dust into concrete, the amount of cement can be reduced. Hence, this study is done to review the mechanical properties and structural behavior of concrete incorporating marble dust. Several research through journals, websites and library were prepared to study the effectiveness of marble dust and its characteristics as a cement replacement in concrete mixture. Most of the previous studies shows that the performance of concrete incorporating marble dust is quite good since it can improve the cement particle without any loss of strength. Most of the previous research has investigate the concrete with the various amount of marble as cement replacement (0%, 5%, 10%, 15% and 20%). The samples then were tested to identify the mechanical properties and structural behavior after 7 and 28 days. The compressive strength of the concrete incorporating marble dust increases gradually until 10% of marble dust and start to decrease at 15%. The split tensile strength and flexural strength of the concrete mixture increased with 15% marble dust, but decreased when it reached the limit. The amount of marble dust in concrete admixture to have the higher compressive strength and greater maximum flexural strength compared to conventional concrete is 10%.

Keywords: Marble Dust, Concrete, Structural Behavior, Mechanical Properties

1. Introduction

Speedy economic growth as well as urbanization have resulted in land limits that challenge civil engineers to construct large-scale buildings. Simultaneously, environmental pollution also swelling at the equivalent proportion with the increasing necessities. Unintentionally, the building construction can source to the environmental pollution due to the usage of concrete. Conventional concrete is the utmost

**Corresponding author: wigoh@uthm.edu.co*

material that were utilized in the structure. It is an important material in building construction since it does not burn, corrode or decay (Joshi & Pitroda*, 2020). Moreover, concrete persists decades longer than alternate construction materials and essentially gets sturdier over period. The production of concrete involves the cement, aggregate and water to be mixed altogether based on their ratio. Cement act as a binder in concrete that set, hardens and adheres to the other materials to bind them together. However, the problem of cement is it release the carbon dioxide to the atmosphere when it reacts with the water and can cause illness to the people. For that reason, there are many binders that can be utilized as a cement replacement to reduce the amount of cement in concrete including marble dust or marble slurry.

Marble was formed from metamorphic rock that self-possessed of recrystallized carbonate minerals, generally calcite and dolomite. The waste that formed during the cutting process of marble called marble dust. In general, it is a very harmful material which can roots to the eye irritation and leads to the infections of the respiratory system. Nevertheless, the marble dust usually left abandoned in the open field without proper management. Therefore, the marble dust needs passable environmental disposal work to reduce the diseases problems. Consequently, marble dust can be utilized as a cement replacement in concrete mixture on the way to reduce the amount of cement. The incorporation of marble dust into concrete would make significant environmental and economic contribution.

2. Literature Review

2.1 Concrete incorporating marble dust

The ability to use the solid waste in concrete production carries innovative element to manufacture industry and assist the sustainability of the environment. The marble dust can be used as the construction materials in two ways which are as a cement replacement and as the fine aggregate in concrete mixture. As for this study, the marble dust is used as a cement replacement in producing the concrete since it is one of the economic contributor materials. Moreover, marble dust waste is usually abandoned at the open field and contribute to the environment pollution that might affected the health. Mentioning to several journals that related to this study, the marble dust was tested in concrete by several samples according to their percentage in concrete which started from 0%, 5%, 10%, 20% to 100% replacement ratios by weight of cement and sand. The sample of concrete incorporating various percentages of marble dust then were kept damp for curing purposes for 7 to 28 days and were tested by several concrete test such as slump test, compressive strength test, split strength test and flexural strength test. The material properties, mechanical properties and the structural behavior of concrete incorporating marble dust were identified based on the result of the tests that have been conducted. Result obtained from the research indicate that extensive benefit in plastic and contraction of marble dust and constructive outcome on mechanical properties of the concrete. Concrete made with marble dust as cement replacement achieved better performance compared to concrete made with Portland cement.

2.2 Material Properties of Marble Dust

The observation to the mechanical properties shows that the addition of marble dust would substitute the fine material transient over a 0.25 mm sieve at certain amounts showed an augmenting outcome on compressive strength. Some test results suggested that the marble dust is suitable for the high performance concrete and their properties are fundamentally better. The study done by Ali et al. (2019) displayed that the mechanical properties of concrete incorporating marble dust tend to deterioration for replacement ratios over 10% but satisfactory results were attained below that level (Demirel, 2010). Even though the compressive strength of concrete incorporating marble dust increases gradually for 0% to 10% of marble dust, still the strength decrease slowly at 15% of marble dust in concrete.

2.3 Mechanical properties of marble dust

The mechanical properties of concrete incorporating marble dust can be identified based on the compressive strength, splitting tensile strength, modulus of elasticity and flexural strength of the concrete. Those results can be obtained through several tests that are commonly used in civil engineering industry.

2.3.1 Compression strength

Referring to R. Kumar & Kumar, (2018), the compressive strength of concrete increases up to a 10% replacement of marble dust in the concrete mixture, but when the proportion of marble dust is increased. Katuwal et al., (2017) indicate that compressive strength of concrete increases at 10% replacement of cement by marble dust and can be satisfactorily done as the compressive strength is greater than the target mean strength.

Shirule, P.A. and Ataur Rahman (2012) had conducted study regarding partial replacement of cement with marble dust. Based on the study, the inclusion of 10% of marble dust increases the compressive strength of the concrete up to 12% for 7 days and 17.7% for 28 of curing days and starts to decrease gradually at 15% of marble. In the studied done by Siva Kishore and Ch. Mallika Chowdary (2015), concrete incorporating marble dust with percentages of 0%, 5%, 10%, 15% and 20% were tested after 7 and 28 days. The compressive strength of concrete with the presence of 15% of marble dust has increase and show positive result compared to 0% of marble dust in concrete.

Other than that, it was shown that 25% of marble dust increases the compressive strength of the M15 grade concrete and starts to decrease whenever there is any further addition of marble dust (Ofuyatan et al., 2019). Another study that had been conducted by *Ayyappan K.* (2018) shows that the addition of 10% of marble dust has increase the compressive strength until it reaches a point where it begins to decline at 15% of marble dust.

Referring to the previous study, the compressive strength of concrete integrating MP was lower than that of control concrete without any addition of marble dust at an early age of curing day. Nevertheless, at 90 days, the concrete incorporating marble dust developed significant strength. As 5% and 10% marble dust were added, it increased by 16.65 % and 17.27 %, respectively, when compared to the control sample (Kanhar et al., 2021).

2.3.2 Split tensile strength

Similar to the compressive strength test, the split tensile strength of concrete increases when 15% of the cement is replaced by marble dust, and as the percentage of marble dust increases, the split tensile strength of concrete decreases (R. Kumar & Kumar, 2018). The split tensile strength test has been conducted on the 7^{th} day to check the gain in initial strength of concrete while 28 days test gives the data of final strength of concrete at 28 days curing. The split tensile strength of cylinders are increased with addition of waste marble powder up to 10% replace by weight of cement and further any addition of waste marble powder decreases the split tensile strength (Shirule, P.A., Ataur Rahman, 2012).

Another study that had been conducted by Ofuyatan et al., (2019) found that the split tensile strength of M15 grade concrete increases by up to 35 % when the amount of marble dust powder is increased at both 7 and 28 days. At 7 and 28 days, the split tensile strength of M15 grade concrete increased by 15.55 % and 17.95 %, respectively. There is, however, a connection between tensile strength and percentage replacement. The marble dust's filling capacity and cohesive characteristics inside the concrete mix account for this improvement in strength.

In a prior study, marble dust was used to partially substitute cement in concrete, with percentages of 5 %, 10 %, 15 %, and 20 %. When 10% of the cement is substituted with marble dust, the split tensile

strength of concrete increases by 12.3% when compared to control concrete. The split tensile strength of the concrete decreases when the marble dust is replaced after 10 % (A. Kumar, 2018).

2.3.3 Flexural strength

Flexural strength rises up to 15% when cement is replaced with marble dust, but as the quantity of marble dust increases, flexural strength decreases (R. Kumar & Kumar, 2018). Partially replaced cement with marble dust at variations of 5%, 10%, 15% and 20% increases the flexural strength up to 14.20% by 10% of marble dust when the cement has been replaced as compared with control concrete. On replacing the marble dust after 10% then there is decrease in the flexural strength of the concrete (A. Kumar, 2018).

Referring to the previous study that had been conducted by (Kanhar et al., 2021), concrete's flexural behavior followed the same pattern as compressive strength. The flexural strength of concrete integrating marble dust is slightly reduced at an early age, but when the curing time is increased, the flexural strength of concrete incorporating marble dust increases.

2.4 Structural behavior of marble dust

The crack pattern of concrete with the presence of marble dust did not appear in the beginning of the test. The cracks started to propagate when the load were applied continuously. Most of the cracks initiated from the bottom of the beam and propagated to the top of the beam. The mode of failure was quite same as the crack spacing was less in concrete replaced with marble dust (Ngullie, 2019).The deflection of the concrete incorporation marble dust was increased up to the ultimate load beyond yielding. The failure of control specimen occurs before the failure of beams replaced with marble dust indicate that the concrete with the marble dust is more ductile compared to the conventional concrete as it is capable of undergoing more deflection before failure (Talah et al., 2015).

In addition, the beam's stiffness was calculated as the ratio of the area of the load deflection curve until the ultimate load to the area of the load deflection curve until the first fracture load. Thus, the durability of the concrete incorporating marble dust is found to be in agreement with conventional concrete (*Ayyappan K.*, 2018). Aside from that, the displacement ductility can be determined as the ratio of ultimate load displacement to yield load displacement. The ductility of concrete incorporating marble dust was measured to be greater than the conventional concrete (A. Kumar, 2018). Finally, the load deflection plot corresponding to the point where the curve deviates from linearity was used to identify the first crack load. The yield moment and yield load were calculated from the from the yield moment. According to the test, the ultimate load of concrete with marble dust replacement was greater than conventional concrete (Seghir et al., 2019).

3. Results and Discussion

3.1 Structural behavior of marble dust

According to various studies that has been done, the ideal proportion of marble dust that should be used in concrete to provide better compressive strength, split tensile strength and flexural strength is 10%. The comparison of optimum percentage of marble dust were shown in Figure 3.1 which most of the studies mentioned that 10% of marble dust is the ideal proportion to achieve highest strength compared to the conventional concrete.

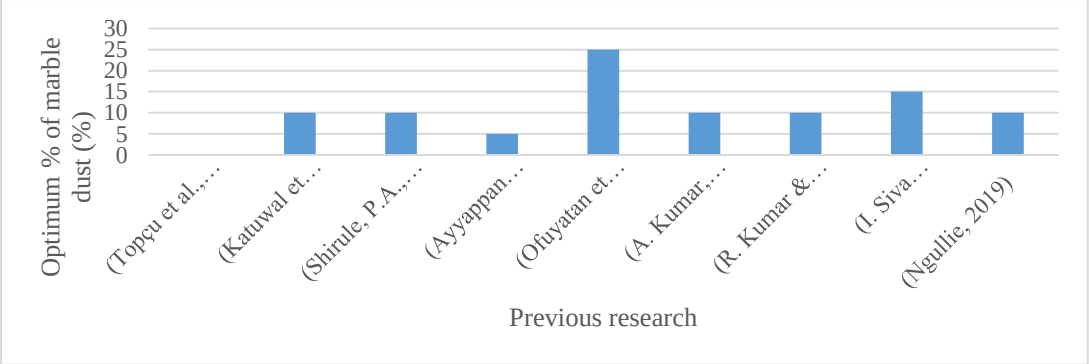

Figure 3. 1: Optimum percentage of marble dust from previous research

The highest compressive strength gained was 25% of the presence of marble dust in concrete mixture as shown in Figure 3.2. However, most of the research obtained the same percentage of marble dust which is 10% for the increases of compressive strength. Nevertheless, the compressive strength of concrete incorporating higher content of marble dust decreased start at 15% of marble dust. This was due to the decreased amount of cement proportion and ultimately leads to a deprived bonding between aggregate and matrix in concrete mixture.

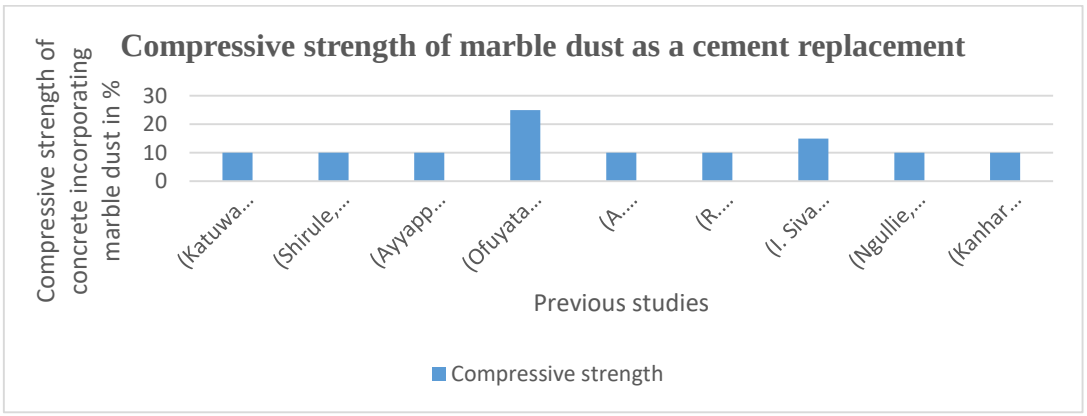

Figure 3. 2: Compressive strength of marble dust from previous research

Comparable to compressive strength, the split tensile strength start to decrease when it reach its limit since the cement proportion is decreases as well. For an instant, R. Kumar & Kumar, (2018) had proved through his journal that 0% to 15% of marble dust has increases the tensile strength test but decrease gradually once it reach the limit which is by 20%. The comparison of previous studies regarding the split tensile strength was shown in Figure 3.3.

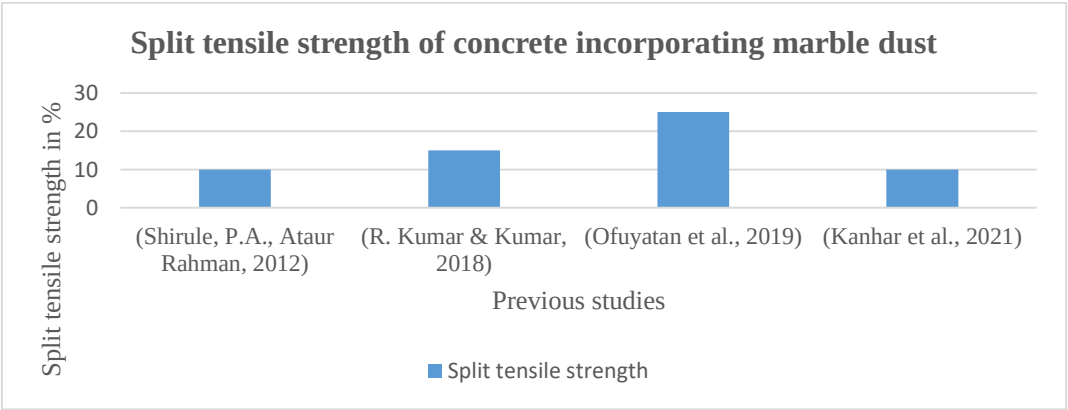

Figure 3. 3: Split tensile strength of marble dust from previous research

The flexural strength of concrete incorporating various percentage of marble dust will increased as compared to Portland cement. R. Kumar & Kumar, (2018) had proved that the concrete incorporating 15% of marble dust increased the flexural strength for 7 days by 7.49% as compared to Portland cement while 7.50% for 28 days after curing. Ayyappan K. (2018) and A. Kumar (2018) also obtained the same percentage of marble dust which is 15% to upsurge the flexural strength of the concrete incorporating marble dust. Thus, it can be clinched that the percentage of marble dust that needed in concrete to achieve higher flexural strength is 15%.

3.2 Structural behavior of marble dust incorporate marble dust

The structural behavior of concrete were defined through compressive strength test, splitting tensile strength test and flexural strength test which identifies the crack patterns and failure mode of concrete, the deflection of the structure during withstand the load, the durability of the concrete and ultimate load of concrete.

The crack pattern of concrete incorporating marble dust did not appear in the beginning of the test and started to promulgated when the load applied continuously. Other than that, the deflection of the concrete with the presence of marble dust was increased up to the ultimate load beyond yielding. The failure of control samples occurs before the failure of beams replaced with marble dust indicate that the concrete incorporating marble dust is more ductile compared to Portland cement since it is capable of undergoing more deflection before failure. Plus, the stiffness of the samples was taken as ratio of area of the load deflection curve till the first crack load.

Although, the durability of the concrete with the presence of marble dust is found to be in settlement with Portland cement. Other than that, ductility of concrete incorporating marble dust was measured to be greater than the conventional concrete. Finally, the load deflection plot corresponding to the point where the curve deviates from linearity was used to identify the first crack load. According to the test, the ultimate load of concrete with marble dust replacement was greater than conventional concrete.

4. Conclusion

The first objective of this study was to review the optimum percentage of marble dust that effects the mechanical properties when marble dust is replaced into concrete mixture. Revolve on the previous research, the optimum percentage of marble dust that effects the compressive strength, split tensile strength and flexural strength was 10% which replacement of cement with marble dust gives an excellent result in strength, as compared to the conventional concrete.

The second objective was to define the mechanical properties of marble dust as a cement replacement in concrete. Referring to the previous research, the mechanical properties of concrete incorporating marble dust shows a good improvement which all compressive strength, split tensile strength and flexural strength has increase compared to the conventional concrete. All the mechanical properties of concrete incorporating marble dust which are compressive strength, split tensile strength and flexural strength increases up to 10% with the presence of 10% to 15% of marble dust in concrete mixture. However, further addition of marble dust in concrete mixture will decrease the strength of the concrete once it reached the limits.

The last objective of this study was to determine the structural behavior of concrete incorporating marble dust. The results of the previous study also suggest that concrete with marble dust performs better than conventional concrete. It is because marble dust-infused concrete is stronger, more durable, and capable of withstanding greater loads and deflection. Furthermore, with the inclusion of marble dust, the deflection of the concrete was enhanced up to the maximum load beyond yielding. Furthermore, the stiffness of the samples was calculated as a proportion of the area of the load deflection curve until the first crack load. Although, in the presence of marble dust, the concrete's durability is shown to be comparable to Portland cement. Besides, the ductility of marble dust-infused concrete was

found to be higher than that of normal concrete. Finally, the test conducted shows that the ultimate load of concrete with marble dust replacement was higher than regular concrete.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Joshi, M. G., & Pitroda*, J. R. (2020). Utilization of Marble Waste in Lightweight Concrete Replacing Fine Aggregates: a Review. Indian Journal of Applied Research, 2, 1–2. https://doi.org/10.36106/ijar/5818082

[2] Demirel, B. (2010). The effect of the using waste marble dust as fine sand on the mechanical properties of the concrete. International Journal of Physical Sciences, 5(9), 1372–1380.

[3] Kumar, R., & Kumar, S. K. (2018). " Partial Replacement of Cement with Marble Dust Powder " “ Partial Replacement of Cement with Marble Dust Powder .” 5(August 2015), 106–114.

[4] Katuwal, K., Duarah, A., Sarma, M. K., Rahman, M., & Sonowal, P. (2017). Comparative Study of M35 Concrete using Marble Dust as Partial Replacement of Cement and Fine Aggregate. 2011, 9094–9100. https://doi.org/10.15680/IJIRSET.2017.0605108

[5] Shirule, P.A., Ataur Rahman, R. D. G. (2012). Partial Replacement of Cement With Marble. International Journal of Advanced Engineering Research and Studies, 1(3), 175–177.

[6] I. Siva Kishore, & Ch. Mallika Chowdary. (2015). a Study on Waste Utilization of Marble Dust in High Strength Concrete Mix. International Journal of Civil Engineering and Technology , 6(12), 1–7.

[7] Ayyappan K. Study on structural behavior of marble dust in concrete, (2018).

[8] Ofuyatan, O. M., Olowofoyeku, A. M., Obatoki, J., & Oluwafemi, J. (2019). Utilization of marble dust powder in concrete. IOP Conference Series: Materials Science and Engineering, 640(1). https://doi.org/10.1088/1757-899X/640/1/012053

[9] Kanhar, R. A., Memon, M. J., Sandhu, A. R., Jhatial, A. A., & Mastoi, A. K. (2021). Mechanical Properties of Concrete Incorporating Marble Powder as Partial Cement Replacement. Quaid-e-Awam University Research Journal of Engineering Science & Technology, 19(1), 59–64. https://doi.org/10.52584/QRJ.1901.08

[10] Kumar, A. (2018). Structural Behaviour of Plain Cement Concrete With Marble Dust Powder and Steel Fibres. International Journal of Modern Trends in Engineering & Research, 5(2), 37–48. https://doi.org/10.21884/ijmter.2018.5034.zgpda

[11] Ngullie, E. C. (2019). A Comprehensive Study on Behaviour of Concrete with Partial Replacement of Cement and Fine Aggregates with Industrial Waste as Marble Powder and Copper Slag – A Review. 2652–2654.

[12] Talah, A., Kharchi, F., & Chaid, R. (2015). Influence of Marble Powder on High Performance Concrete Behavior. Procedia Engineering, 114, 685–690. https://doi.org/10.1016/j.proeng.2015.08.010

[13] Seghir, N. T., Mellas, M., Sadowski, Ł., Krolicka, A., Zak, A., & Ostrowski, K. (2019). The utilization of waste marble dust as a cement replacement in air-cured mortar. Sustainability (Switzerland), 11(8), 1–14. https://doi.org/10.3390/su11082215