Influence of Dolomite and Granite Waste Content on The Properties of Artificial Marble

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Abstract: The main objective of this work is to characterize and investigate the effect of mineral dolomite and granite waste content on the physical and mechanical properties of artificial marble. Five different samples of artificial marble were prepared with different proportions of fillers. In this study, granite waste is used as a filler by substituting the dolomite content from 10 wt% to 40 wt%. Test specimens were evaluated for water absorption analysis, flexural, compression and Barcol hardness properties. It is found that the optimum 10 wt% of granite waste in the composition has increased the flexural and compression strength and reduces the water absorption rate, while the substitution of granite waste does not change significantly the Barcol hardness properties.

1. Introduction
Artificial marble also known as synthetic marble or cultured marble and some of called as marble composite. It is formed from a mixture of polymer resin, mineral fillers, catalyst and pigments. Generally, natural marble is highly porous, permeable and have higher tendency to cracking, chipping and discoloring. Extra process and high maintenance are thus required to prevent such problems. Furthermore, the complexity of the processes such as quarrying, slab cutting and transporting has resulted in increasing the production cost of the natural marble. To overcome these difficulties, artificial marble is produced artificially and the usage is increasing due to depleting supply of natural marble.

Artificial marble is a versatile material created in various natural color, design and patterns which mimic the look of natural marble, granite and quartz. Various techniques like casting, isostatic pressing, and dry casting are used to cast the artificial marble. In artificial marble composition, filler is used as an aggregate while resin is acts like glue hence strengthening the marble. Artificial marble has a wide range of application includes as floor and wall tiles, solid surface kitchen countertops, sinks, bathtubs, bathroom vanities and etc. In most of the artificial marble manufacturing industries, imported alumina tri-hydrate (ATH) filler, limestone or marble dust/powder/particles are commonly used as the main raw material.

In this study, dolomite is introduced as the main filler to substitute the limestone and marble dust/powder/particles. Dolomite is a sedimentary carbonate rock mineral which contains of calcium and magnesium carbonate with chemical composition of \(\text{CaMg(CO}_3\text{)}_2\). In Malaysia, dolomite is the most abundant carbonate mineral after limestone which mainly used as an aggregate for road construction and soil fertilizer. Dolomite has a significant potential to be explored as it shares similar properties with limestone. Therefore, the application of dolomite in many industries should be studied and carried out to increase the diversity.
Besides dolomite, granite aggregates is the main mineral resources available in the country. Granite was quarried as a dimension stone; crushed stone or aggregate for road construction, railroad foundations and for building applications like paving, monuments, countertops and floor tile. The used of granite waste as filler in the production of artificial marble is being studied in the present work due to the high production of crushed granite that generates a dumping of waste. A million tonnes of waste from quarry industries are being released from crushed activity, cutting, processing and grinding. In dry season, the granite powder or dust dangles in the air, flies and deposits on vegetation and crop. All these conditions are significantly affecting the environment and local ecosystems. By considering the existing available of local mineral resources and quarry industrial waste, this study offers an alternative material in manufacturing of artificial marble by combination of dolomite and granite waste as a filler in the matrix of polyester resin. Hence, the objective of this work is to characterize and investigate an influence of both materials on the properties of artificial marble.

2. Materials and methods

2.1 Materials

The local dolomite was supplied by dolomite quarry from Perlis, while granite waste was collected in Keramat Pulai, Perak. Dolomite and granite waste were grounded into powder form using planetary ball milling with a speed of 250 rpm for 15 minutes for mineral characterization. Both raw materials have been characterized using X-ray diffractometer (XRD) (D8 Advanced, Bruker, German) and X-ray fluorescence (XRF) spectrometer (Shimadzu XRF-1700). In this study, polyester resin is used as the polymer matrix and methyl ethyl ketone peroxide (MEKP) was added to be functioned as hardener with the amount of 1 wt% from resin content. Figure 1 shows the images of dolomite and granite waste used in this study.

![Figure 1. (a) dolomite (b) granite waste.](image)

2.2 Preparation of artificial marble

The origin size of dolomite used in the preparation of artificial marble is 2.00 mm while granite waste contained of powder and dust have a maximum aggregate size of 2.36 mm. The mixture of polyester resin and fillers were well mixed at 200 rpm using a planetary mixer about 10 to 15 minutes and stirred until the fillers is evenly dispersed and wetted by the resin. Then, MEKP is added to initiate the polymerization reaction and the mixture was cast into the mold and left for curing for a few hours or until fully set. A total of 5 samples have been prepared from the base ratio of 70:30 (filler:matrix resin) in weight %. Table 1 shows the mix proportions of artificial marble.
Table 1. Mix proportions of artificial marble.

| No | Sample        | Resin (% wt) | Dolomite (% wt) | Granite waste (% wt) |
|----|---------------|--------------|-----------------|----------------------|
| 1  | D70 (control) | 30           | 70              | 0                    |
| 2  | D60GW10       | 30           | 60              | 10                   |
| 3  | D50GW20       | 30           | 50              | 20                   |
| 4  | D40GW30       | 30           | 40              | 30                   |
| 5  | D30GW40       | 30           | 30              | 40                   |

** Notes: D=Dolomite; GW=Granite waste

2.3 Characterization of artificial marble

Sample of artificial marble was set for physical and mechanical analysis. The water absorption test was conducted according to ASTM D785. A square test specimen with dimension size of 12.7 mm x 12.7 mm x 12.7 mm was prepared. The weight of the specimen is measured in air ($W_1$) and then the specimen was immersed in distilled water for 24 hours. On removal from water, the specimen need to wipe off and specimen weighed again ($W_2$). Water absorption was calculated as below equation:

$$\text{Water absorption (\%)} = \left( \frac{W_2 - W_1}{W_1} \right) \times 100$$ (1)

Flexural test of the cured marble was performed according to ASTM D790. In order to determine the flexural strength, the dimension of 25.4 mm x 12.7 mm x 8 mm rectangular bars specimens was prepared. The test was conducted under 3-point loading at a cross-head speed of 0.2 mm/min and the support span length is 20 mm. The compression test also was performed according to ASTM D695. The dimension size of marble specimen is 12.7 mm x 12.7 mm x 12.7 mm. Both flexural and compression test are performed using the Instron Universal Testing Machine (UTM, Model 3366, Instron).

Barcol hardness test is performed using a portable Barcol Hardness Impresor in order to determine the hardness by indentation of material through the depth of penetration on the indenter. The dimension size of marble specimen is 50 mm x 50 mm x 8 mm as recommended in ASTM D258. Data is expressed as Barcol numbers given by the instrument which the reading on a 0 to 100 scale. A 10 readings of measurement were indicates and the average value was calculated.

3. Results and discussion

3.1 Characterization of raw materials

Figure 2 shows the XRD pattern of dolomite and granite was. The main peak observed in the dolomite sample corresponds only to mineral dolomite. While, XRD analysis on granite waste reveals the presence of mineral quartz, albite, microcline and calcite as the main mineral. The chemical composition of the dolomite and granite waste is listed in Table 2. The main composition of dolomite is calcium oxide (CaO) and magnesium oxides (MgO) with the contents are 30.28% and 20.08%, respectively. While, granite waste shows the main oxide presented are silicon dioxide (SiO$_2$) and alumina oxide (Al$_2$O$_3$) with the composition are 75.44% and 12.47%, respectively.

The carbonate content of dolomite is fundamental in determining the chemical purity of the resources and is the basis of chemical grade dolomite classification. Table 3 is listed the types of carbonate rock based on calcium carbonate (CaCO$_3$) content. The value of CaCO$_3$ can be determined as the following calculation:

$$\% \text{ CaO} \times \text{Conversion Factor} = \% \text{ CaCO}_3; \text{ conversion factor is 1.78}$$ (2)
From the calculation, the obtained value of CaCO$_3$ in dolomite sample is 53.89% and classified as pure dolomite rock. This result is in agreement with the XRD analysis which the main phase found only dolomite mineral. From this analysis and based on the calcium carbonate content, dolomite is found to have a potential to replace partially the properties of limestone and marble and granite waste is combined with dolomite to increase the physical and mechanical properties of artificial marble.

![Figure 2](image-url)  
*Figure 2. XRD pattern of (a) dolomite (b) granite waste.*

**Table 2.** Chemical composition of dolomite and granite waste.

| Sample          | Oxides (%) | LOI (%) |
|-----------------|------------|---------|
|                 | SiO$_2$    | Al$_2$O$_3$ | CaO | MgO | Fe$_2$O$_3$ | K$_2$O | Na$_2$O | TiO$_2$ | MnO | Cr$_2$O$_3$ | ZrO$_2$ | LOI (%) |
| Dolomite        | 0.63       | 0.20     | 30.28 | 20.08 | 0.24         | 0.03    | 4.10    | 0.02    | -   | -           | -       | 47.36    |
| Granite Waste   | 75.44      | 12.47    | 1.21  | -     | 1.27         | 6.18    | -       | -       | -   | -           | -       | 47.36    |

**Table 3.** Types of carbonate rock based CaCO$_3$ content.

| CaCO$_3$ content (%) | Types of carbonate rock |
|----------------------|--------------------------|
| < 58.85              | Dolomite                 |
| 58.85-77.14          | Calcitic Dolomite        |
| 77.14-95.43          | Dolomitic Limestone      |
| 95.43-97.71          | Magnesian Limestone      |
| >97.71               | Limestone                |
3.2 Characterization of artificial marble

Figure 3 shows the marble specimens in water bath during water absorption test while Figure 4 represents the result of water absorption versus composition of artificial marble with different filler of dolomite and granite waste contents. The water absorption was varies between 0.270% to 0.328% and the value water absorption does not change significantly between control sample and the marble sample content of granite waste at 10 wt% (D60GW10). As can be seen, there is generally a slight increase in water absorption with replacement of granite waste content from 20 wt% to 40 wt%. It might be due to the non-homogeneous particle size of granite waste which formed in the powder, fine dust and large particles. As the granite waste content increased, the powder and fine dust in the mixture could contributed to increase the viscosity of mixture and lead to produce a pores. However, the value found in the present work is acceptable as literature reported the range of water absorption for artificial marble in industries is from 0.09% to 0.40%.

![Figure 3. Marble specimens soak in water bath for water absorption test (from top view).](image)

![Figure 4. Water absorption of artificial marble.](image)
Figure 5 shows the result for flexural strength versus composition of artificial marble with different filler of dolomite and granite waste contents. It was seen that flexural strength increase with replacement of granite waste by 20 wt% and among all the samples, D60GW10 was found to be the highest strength. This was believed due to high hardness of granite waste that contained of mineral quartz in the composition. Unexpectedly, artificial marble decreased with increasing granite waste content until it reached a maximum value at 40 wt%. The decrease of flexural strength can be explained by powder and fine dust of granite waste particles, which exhibited a higher surface area and subsequently resulting agglomerates. An agglomeration increases the average particles size by the combination of powder particles and acted as stress concentrations or weak point that breaks when stress is applied, hence decreasing the flexural strength.

![Figure 5. Flexural strength of artificial marble.](image)

Figure 6 shows the compression test images of artificial marble during testing and Figure 7 shows the result for compression strength versus composition of artificial marble with different filler of dolomite and granite waste content. The compression strength value of marble samples containing of granite waste was determined between 83.11 MPa and 89.93 MPa. These values were lower than the value of the control sample, which was 93.65 MPa. The decrease may be attributed to the increasing viscosity of the mixture which caused the increase of pores formation during the casting. This subsequently introduced a weak point in the sample, thereby decreasing the compression strength. This result can be supported by the increase of water absorption rate composed of granite waste from 20 wt% to 40 wt% as observed in Figure 4.

![Figure 6. Compression testing.](image)
Figure 7. Compression strength of artificial marble.

Figure 8 shows the Barcol hardness result of the artificial marble versus composition of artificial marble with different filler of dolomite and granite waste content. From the figure, it is found that Barcol hardness slightly decreases with the replacement of granite waste until maximum at 40 wt%. Apparently, that replacement of granite waste does not change significantly the Barcol hardness properties. However, the value of Barcol hardness found in this study is in the range of the commercial value measured in industries, which was between 45 HBa to 65 HBa.

4. Conclusion
The present study focusing on improving the physical and mechanical properties of artificial marble composed with dolomite and granite waste filler. The test result shows that, the water absorption value was increases and the flexural and compression strength slightly decreases as the content of granite waste replacement increases to the maximum at 40 wt%. The decreases of the mechanical properties can be related to the powder and fine particle in granite waste that contribute to the increase of mixture viscosity. However, the optimum 10 wt% of granite waste replacement gives better properties which demonstrated a low water absorption, and higher flexural and compressive strength. Dolomite and
granite waste seems have a good potential to utilize as filler in the manufacturing of artificial marble. However, some recommendations for the future studies are suggested such as morphology analysis and method of development by using a vacuum mixer to reduce the existing pores.

5. References

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