The effects of mineralogical and petrographical features of the Lake District rocks (Isparta, Turkey) on the quality of artificial marbles

1. Introduction

Wastes of rocks similarly to all kinds of construction materials and industrial raw materials used in our daily life may adversely influence the environment. Evaluation of the waste materials and turning into economic value has important issue at present time. Large quantities of marble blocks are produced from many new marble quarries which were opened around Isparta (Turkey) and its surrounding region. The opened quarries are also affected negatively by weathering as a result of karstification. Therefore, block efficiency of the quarries is low which results in a lot of waste materials that can be used in cultured marble production. The production of artificial marble from marble waste materials around Isparta is the main purpose of the study. The cultured marble is an attractive, healthy and homogenous building material. It has a wide application in the building construction sector. Artificial marble which is composed of mineral dusts and polyesters has high mechanical strength and they are durable to various chemical and high temperature environmental conditions. Based on physico-mechanical properties, cultured marbles are accepted by Turkish Standards (TS). The materials used for the production of qualified cultured marble are directly related to the hardness of the minerals used as filler in the polyester resin. Physico-mechanical properties of cultured marble depend on the physical properties of the filler minerals. The compressive strength of the cultured marble material is controlled by the physical properties of the filler minerals, therefore, the hardness of the cultured marble is determined by the hardness of the filler mineral. The following analyses were carried out: wet unit volume analysis, dry unit volume analysis, compressive strength of the materials, capillary water absorption analysis, analysis of ultrasound velocity (P-wave) and the marble wastes bulk chemical analyses were investigated and the results of the data were evaluated and discussed. In addition, natural and artificial marbles were compared with respect to physico-mechanical properties.

Keywords: artificial marble, polyester resin, marble quarry, compressive strength.

Abstract

Large quantities of marble blocks are produced from many new marble quarries which were opened around Isparta (Turkey) and its surrounding region. The opened quarries are also affected negatively by weathering as a result of karstification. Therefore, block efficiency of the quarries is low which results in a lot of waste materials that can be used in cultured marble production. The production of artificial marble from marble waste materials around Isparta is the main purpose of the study. The cultured marble is an attractive, healthy and homogenous building material. It has a wide application in the building construction sector. Artificial marble which is composed of mineral dusts and polyesters has high mechanical strength and they are durable to various chemical and high temperature environmental conditions. Based on physico-mechanical properties, cultured marbles are accepted by Turkish Standards (TS). The materials used for the production of qualified cultured marble are directly related to the hardness of the minerals used as filler in the polyester resin. Physico-mechanical properties of cultured marble depend on the physical properties of the filler minerals. The compressive strength of the cultured marble material is controlled by the physical properties of the filler minerals, therefore, the hardness of the cultured marble is determined by the hardness of the filler mineral. The following analyses were carried out: wet unit volume analysis, dry unit volume analysis, compressive strength of the materials, capillary water absorption analysis, analysis of ultrasound velocity (P-wave) and the marble wastes bulk chemical analyses were investigated and the results of the data were evaluated and discussed. In addition, natural and artificial marbles were compared with respect to physico-mechanical properties.

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1. Introduction

Wastes of rocks similarly to all kinds of construction materials and industrial raw materials used in our daily life may adversely influence the environment. Evaluation of the waste materials and turning into economic value has important issue at present time. Large quantities of marble blocks are produced from many new marble quarries which were opened around Isparta (Turkey) and its surrounding region (Fig. 1). The opened quarries are also negatively affected by weathering as a result of karstification. Therefore block efficiency of the quarries is low and they produce a lot of waste materials [1]. There are many ways to evaluate these produced wastes [2]. Granulated artificial marble dusts in micron size in mills mixing and molding in different ratios with resins have been evaluated as cultured marble artificial construction material [3]. One of the evaluation methods of waste marble is using them in production of cultured marble. The production of artificial marble from natural marble waste materials around Isparta-Burdur area is the main purpose of this research.

Marble blocks produced at marble quarries leave huge quantities of marble wastes which results waste marble hills with visual pollution (Fig. 2) [2]. Wollastonite, quartz and other silicate minerals are significant materials used for artificial marble production as well, additional to marble waste. Calcite and dolomite are considered in carbonate group minerals and the effect of the ratios of the resins and additive materials on cultured marble materials is still under discussion [4].
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2. Materials and methods

2.1. Samples location

There are many marble deposits around Isparta and Burdur area. We have collected 12 samples from waste marbles; locations are indicated in Fig. 3.

2.2. Used materials for artificial marble production

Artificial marbles have been produced from calcite, quartz, feldspar and wollastonite that can be found in waste marble dusts mixing with polymer resin materials. Resins are used as binder, calcite, dolomite, quartz and wollastonite minerals are used as aggregate/filler for cultured marbles and waste glass is also used for artificial marble production as additive material [5].

3. Results and discussions

3.1. Texture of artificial marbles

Polarization microscopy analysis was made first to study the texture of artificial marble raw materials. For the inspection, sections of 30 μm thickness were prepared to identify the mineral composition of the waste marble samples. Some of the samples could not be determined by means of polarization microscopy due to the grain size smaller than 2 μm. Those samples were investigated by differential thermal analysis (DTA) and scanning electron microscope (SEM). The texture of sedimentary marbles was found to be micritic texture; the andesites have porphyritic texture which has phenocrysts in glass. The scanning electron microscope investigation of the texture of the produced cultured marble is shown in Fig. 4. It has clastic texture where the grains are marble surrounded by the resin. The resin is amorphous material, therefore, the light cannot be transmitted through it (appears in dark colour in Fig. 4). Calcite grains are transparent and permit the light transmitting through them (appear in light colour in Fig. 4).

3.2. Characterization of the artificial marble

For the characterization of the calcite and dolomite minerals, SEM and DTA analyses were carried out (Fig. 4 and 5). Sedimentary marbles have micritic texture containing micritic types of calcite and dolomite minerals depending on their composition. They could not be determined by polarization microscopy, therefore, we applied differential thermal analysis (DTA) to study the mineralogical composition, by preparing powder sample. The sample was heated up to 1200°C and exothermic and endothermic peaks were noted at certain points. Endothermic peaks between 800 and 900°C belong to calcite and dolomite. The obtained results were evaluated by ASTM cards which confirmed the composition of minerals being a mixture of dolomite and calcite.

3.3. Properties of the artificial marbles

Chemical composition of marble is changing with respect to the type of marbles. Igneous marbles have high SiO₂ but sedimentary types of marbles have higher Ca-Mg-CO₃ (Table 1).

Mineralogy of the minerals used as an additive in artificial marbles controls the quality of the cultured marbles. Therefore, mineralogy of the used additive materials has to be investigated in detail with respect to physical properties. These are especially hardness, grain size and morphology and thermal properties. Raw waste marble samples contain calcite, dolomite, quartz, mica, feldspar, serpentine group minerals and wollastonite.
Calcite and dolomite belong to carbonate group minerals. Their hardness values are 3 and 4 with respect to Mohs hardness scale, respectively. When artificial marble is produced by using carbonate minerals its compressive strength is lower. As hardness of the minerals increases, its compressive strength increases too. On the other hand, trachy-andesites containing feldspar and quartz which belong to silicate group minerals give higher compressive strength and have higher hardness value between 6 and 7 with respect to Mohs hardness scale.

In artificial marble production, grain size morphology is important if high temperature resistant material is intended to be produced. Wollastonite has fibrous grain morphology and is resistant to high temperature [6]. It has a unique property with fibrous morphology and also refractory feature (Fig. 6). The materials containing wollastonite can be used effectively in high temperature conditions. It has also high corrosion resistance. When it is used as an additive material in artificial marbles it may result higher compressive strength, higher durability, refractory feature and corrosion resistance.

| Sample Number | Limestone | Trachyandesite | Travertine |
|---------------|-----------|----------------|------------|
| Number        | GY1       | GY2            | GY3        |
|               | GY4       | GY5            | GY6        |
|               | GY7       | GY8            | GY9        |
|               | GY10      | GY11           | GY12       |
| SiO₂          | 0.11      | 0.09           | 0.02       |
|               | 0.16      | 0.07           | 0.01       |
|               | 0.01      | 0.1            | 0.02       |
|               | 0.07      | 0.01           | 0.07       |
|               | 57.6      | 0.21           | 0.03       |
| TiO₂          | 0         | 0              | 0          |
|               | 0         | 0              | 0          |
|               | 0         | 0              | 0          |
|               | 0.43      | 0.00           | 0.00       |
| Al₂O₃         | 0.01      | 0.01           | 0.02       |
|               | 0.01      | 0.01           | 0.01       |
|               | 0.01      | 0.01           | 0.01       |
|               | 0.04      | 0.01           | 0.04       |
|               | 0.04      | 0.01           | 0.04       |
|               | 17.1      | 0.02           | 0.01       |
| Fe₂O₃         | 0.06      | 0.04           | 0.03       |
|               | 0.06      | 0.04           | 0.05       |
|               | 0.04      | 0.09           | 0.02       |
|               | 0.02      | 0.07           | 0.07       |
|               | 4.14      | 0.20           | 0.05       |
| MnO           | 0.01      | 0.01           | 0.01       |
|               | 0.01      | 0.01           | 0.01       |
|               | 0.01      | 0.02           | 0.01       |
|               | 0.01      | 0.01           | 0.13       |
|               | 0.04      | 0.01           | 0.01       |
| MgO           | 0.61      | 0.56           | 0.74       |
|               | 0.54      | 18.4           | 0.43       |
|               | 0.43      | 0.5            | 0.44       |
|               | 0.43      | 1.33           | 0.40       |
|               | 54.7      | 54.8           | 54.7       |
|               | 54.8      | 54.4           | 54.7       |
|               | 53.5      | 54.8           | 54.9       |
|               | 54.5      | 4.89           | 53.70      |
|               | 54.7      | 54.5           | 54.7       |
| CaO           | 53.3      | 54.1           | 53.8       |
|               | 54.8      | 33.8           | 54.7       |
|               | 53.5      | 54.8           | 54.9       |
|               | 54.5      | 4.89           | 53.70      |
| Na₂O          | 0.52      | 0.49           | 0.49       |
|               | 0.49      | 0.51           | 0.47       |
|               | 0.53      | 0.47           | 0.5        |
|               | 0.47      | 5.0            | 0.46       |
|               | 0.46      | 0.50           | 0.50       |
| K₂O           | 0.58      | 0.56           | 0.56       |
|               | 0.57      | 0.55           | 0.53       |
|               | 0.53      | 0.6            | 0.52       |
|               | 0.52      | 0.57           | 0.48       |
|               | 0.48      | 0.57           | 0.58       |
| P₂O₅          | 0.02      | 0.02           | 0.02       |
|               | 0.03      | 0.04           | 0.01       |
|               | 0.03      | 0.02           | 0.02       |
|               | 0.02      | 0.24           | 0.02       |
|               | 0.02      | 0.01           | 0.01       |
| Ignition lost | 98.9      | 98.9           | 99.2       |
|               | 99.2      | 99.8           | 99.8       |
|               | 99.8      | 99.5           | 99.8       |
|               | 99.5      | 98.6           | 99.2       |
|               | 98.9      | 99.6           | 98.9       |
|               | 99.6      | 99.2           | 99.6       |
|               | 99.2      | 99.9           | 99.70      |

Table 1. Chemical composition of natural marbles which used for artificial marble production.

Grain morphology also controls the quality of artificial marble. Wollastonite and chrysotile have fibrous grain morphology. They contribute to higher strength of the materials similarly to steel rebars in concrete. Although wollastonite and chrysotile are useful for the best quality of the artificial marble but chrysotile is considered to be carcinogenic so it is not preferred for the production of the cultured marble [7,8].

Weights of wet unit volume (WWUV) of artificial marble cubic samples were evaluated (Table 3). Natural marbles have some porosity which adversely affects the quality of the marble. When natural marbles have porosity of percolated capillaries, water may be absorbed into the material and cause the weathering physically and chemically. Therefore, porosity
of the marbles should be close to zero (Table 3). The water absorption was found to be low (values vary between 0.00 % and 0.08 %) for the cultured marble samples tested (Table 3). It means that the products are compact and have negligible amount of porosity. The low porosity can make the material durable against water and air.

| Sample Number | WDUV (kg/m³) | WWUV (kg/m³) | Porosity (n) % |
|---------------|--------------|--------------|----------------|
| GY-1          | 1993.12      | 2004.01      | 5.32           |
| GY-2          | 2015.24      | 2021.15      | 4.12           |
| GY-3          | 2012.89      | 2014.83      | 6.13           |
| GY-4          | 1994.60      | 1997.34      | 6.68           |
| GY-5          | 2044.84      | 2060.28      | 5.08           |
| GY-6          | 1903.50      | 1888.97      | 3.88           |
| GY-7          | 1976.40      | 1972.66      | 3.88           |
| GY-8          | 2010.73      | 2011.22      | 2.40           |
| GY-9          | 1989.50      | 1996.51      | 6.80           |
| GY-10         | 1908.49      | 1908.40      | 10.00          |
| GY-11         | 2026.56      | 2024.98      | 10.00          |
| GY-12         | 1971.53      | 1981.90      | 11.72          |

Table 3: Weights of dry unit volume (WDUV), weights of wet unit volume (WWUV) and apparent porosity of artificial marble cubic samples

Table 4 summarizes the compressive strength, the ultrasound pulse velocity and the rebound index values corresponding to the artificial marbles produced.

| Sample Number | Compressive strength N/mm² | Ultrasound pulse velocity Vp (m/s) | Rebound index |
|---------------|-----------------------------|-----------------------------------|---------------|
| GY-1          | 106.13                      | 3555                              | 34            |
| GY-2          | 98.69                       | 3509                              | 34            |
| GY-3          | 91.21                       | 3478                              | 34            |
| GY-4          | 72.17                       | 3503                              | 34            |
| GY-5          | 64.93                       | 3406                              | 34            |
| GY-6          | 83.51                       | 3271                              | 34            |
| GY-7          | 82.29                       | 3440                              | 34            |
| GY-8          | 97.11                       | 3461                              | 34            |
| GY-9          | 71.86                       | 3426                              | 34            |
| GY-10         | 61.16                       | 3399                              | 34            |
| GY-11         | 76.32                       | 3516                              | 34            |
| GY-12         | 68.88                       | 3601                              | 34            |

Table 4: Compressive strength, ultrasound pulse velocity and rebound index of artificial marble cubic samples

4. Conclusions

Large quantities of marble blocks are produced from many new marble quarries which were opened around Isparta (Turkey) and its surrounding region. Block efficiency of the quarries is low which results in a lot of waste materials that can be used in cultured marble production. The cultured marble is an attractive, healthy and homogenous building material. It has a wide application in the building sector. Artificial marble which is composed of mineral waste materials and polyester resins has high compressive strength, durable to various chemical and high temperature environmental conditions. Based on physico-mechanical properties, cultured marbles are accepted by the Turkish Standards (TS). Physico-mechanical properties of cultured marble depend on the physical properties of the filler minerals. The following analyses; wet unit volume analysis, dry unit volume analysis, compressive strength of the materials, capillary water absorption analysis, ultrasound pulse velocity analysis and the marble wastes bulk chemical analyses were carried out and the results were evaluated and discussed with respect to the physico-mechanical properties.

Table 5. Minimum values required by the uniaxial compressive strength (TS EN 1926)

Table 6. Various physico-mechanical values of resins
Construction materials should have important physico-mechanical values required in building industry. When we compared our artificial marbles with natural building stones, our results all met the requirements. Therefore, our artificial marbles can be safely used in the building industry as a construction material. The artificial marbles are resistant to acids, alkalis and they are cheap and durable so there is a huge potential in them to be used in harsh environments. Artificial marble has anti-bacterial property so it has been widely used in baths, hospitals, hotels, restaurants. Artificial marble production has positive effect on environmental concerns by elimination of marble wastes as well.

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A Lake District közétek (Isparta, Törökország) ásványtani és közvetett jellegzetességeinek hatása mesterséges márványok minőségére

Törökországban, Isparta város környezetében számos márványbánya nyílt az elmúlt évtizedekben. A helyenként számtovette karsztosodás miatt a közöttombók kitermelésének hatékonyága nem optimális, és nagy mennyiségű hulladék márvány töret keletkezik. A hulladék anyag dagolása javítja a viszonyok, szennyezést eredményez. A hulladék márvány alkalmazásával készített mesterséges márvány készítésére, polírtervezet gyánta bimorból, a mesterséges márvány túlmodban hatását mutatja be. Emellett a vizsgált mesterséges márványok fizikai/mechanikai jellemzői és fizikai/mekanikai makela és méretjellemzőit, illetve a mesterséges márványok fizikai/mechanikai jellemzőit és méretjellemzőit.

FOLYÓÍRATSZEMLE

A.Hellebois, A. Launoy, C. Pierre, M. De Lanève, B. Espion: 100-year-old Hennebique concrete, from composition to performance

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A belga szerzők angol nyelvű cikke egy 1904-ben épült, 2010-ben elbontott vasbeton vasút egyik mesterséges márványból készült vizsgálatot mutatja be. A híd (Via duc Colo-Hugues) Belgiumban, Braine-l’Alleud városában épült Hennebique eredeti szabadalma alapján. A híd eredetileg egy 13-nyílású, 73 m hosszú, 18,6 m magas híd volt. A 0,25 mm/0,5 mm frakció a napjainkban megszokottnál nagyobb mértékben található XIV. században, így azok kémiai jellemzőit, fizikai jellemzőit és méretjellemzőit ismertetik.

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