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Investigation on the usage of waste marble powder in cement-based adhesive mortar

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HIGHLIGHTS

- Marble wastes from marble quarries and production facilities are partially reusable.
- There is a feasibility of incorporating the marble powder residue into adhesive mortar.
- The substitution of 40% in the mortar with the residue is satisfactory.
- All the test results for marble powder blended adhesive mortar are within the limits.

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ABSTRACT

In this study, the availability of marble powder (MP) additive at different ratios were investigated instead of dolomite, which is the raw material in adhesive mortars of insulation board. Marble waste powder's humidity, chemical structure and particle size was investigated. Then, compressive – tensile – bending strengths, water absorption, initial setting time, and flow-spreading tests at the adhesive mortars with additive were performed. All results showed that marble waste powder's humidity was lower than 1%, and particle size amounts +710 μm and −125 μm were more than raw dolomite. As a result of the tests, it was determined that the values were obtained in accordance with the relevant EN standards. According to the results of XRD, the ratio of calcium carbonate and hatrurite ratio of marble powder are exceeded. The use of marble powder with dolomite was also investigated economically and it was concluded that it is more advantageous to make cost calculations.

1. Introduction

Marble wastes from marble quarries and production facilities are partially reusable, and a large part is disposed in the surrounding area. There are a lot of scientific studies carried out in order to revaluate wastes of different sizes in industry [1–4]. Approximately 30% of the marbles processed in marble factories are known as production wastes. This causes a lot of waste in Turkey and it will be a great contribution to the economy. In some applications in the world and in the literature, marble waste is evaluated in many sectors such as ceramics, cement, paint, glass, and building materials. One of the areas where this marble powder can be used is the building material sector [5–13].

The marble waste deposit areas in the regions, where the marble processing facilities concentrate, cause reactions due to the environmental issue, and damage to natural beauty in the society. All the small marble pieces and powders that are produced during the extraction of the marbles from the quarry and during the processing of the marble blocks in the factory are accepted as marble waste [14]. Marble wastes are classified as wastes which are generated in quarries and factories according to their places of occurrence. According to their sizes, they are called as unshaped blocks, rubble (in quarry), crushed slabs and sawdust (in the processing plants) [2]. The dust and sand wastes from the marbles processed in the facilities constitute approximately 30% of the processed marbles. Marble sand wastes, which can be used in various industrial areas, can be at a much cheaper cost if they are used instead of their alternatives [15,16]. As a production waste in marble factories dust is generally not reused, and it causes some problems as following: the cost of the landfill, and subtraction of the land from alternative uses. The increase occurring in population and urbanization and quality of life due to some technical innovations leads to an increase in the amount and variety of solid wastes produced in industrial, mineral, domestic and agricultural areas [17]. The use

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of industrial wastes in the development of alternative new materials or as raw materials will provide protection for the environment and keep the cost low [13–18].

During the extraction of marble blocks and processing of blocks, two types of waste are formed, one in the form of dust and the other one in the form of boulders in waste. These wastes cause various negative effects in the environment. Boulders and dust wastes can be transformed into a material with economic added value by considering it as a source of raw materials in various forms. There are many studies on the assessment of dust marble residues in many areas [19,20]. One of them is adhesive materials in the construction sector. An external thermal insulation cladding system is a complex multi-layer system, and each layer displays different properties with semi-elastic bonds between them. Stress is mainly caused by some environmental agents such as rain, sun, wind and others on the system as a whole. Thus, the system reacts in its entirety. To achieve a good system performance, external or dead loads and material properties must be analyzed during the adherent cladding system design process [21]. One of the building materials and used for insulation mantle, as adhesive mortars are used for adhering plates such as extruded polystyrene styropor (XPS), expanded polystyrene styropor (EPS), and rock wool (RW) [22]. In order to set the boards, the polymer-modified mortars, which consist of cement, dolomite, and chemicals, have been mainly used because they improve workability, water retention, mechanical properties, bond strength, flexibility, and hydrophobic properties as compared to the traditional mortars [23,24].

Some researchers have investigated the performance of adhesive mortars with different mineral additives or different chemical admixtures. Azevedo et al. [25] performed a study on the usage of wastes from the wastewater treatment plant of the glass polishing process in adhesive mortar with partial replacement of cement and fine aggregate. The rheological properties were tested by the authors. They found that adhesive mortars with waste glass required high loads to spread the mass and with a poor effect along the application process. Petit et al. [26] investigated the effect of the formulation parameters on adhesive properties of compliant tile adhesive mortars. They considered the influence of percentages by mass of cement, latex polymer and cellulose ether. Experimental results showed that the relative concentrations of constituents exerted an influence on the adhesive properties of the mortars. Petit and Wirquin [27] used cellulose ethers in cement based ceramic tile adhesive mortars. The obtained results indicated that the end-use values either in the fresh or hardened state were strongly influenced by the ratio of latex powder to cellulose ethers choice. Winnefeld et al. [28] investigated the durability properties of adhesive mortars for tile by measuring the length changes of the composite specimens under various curing conditions. They observed that the deformations caused by wetting and drying events were restrained by the stiff tile. Stresses result especially at the edges of the tile, which may cause micro-cracking at the interface of tile and mortar resulting in a reduction of adhesion strength. Almeida and Sichieri [24] used silica fume in polymer-modified adhesive mortars. Additions of silica fume and latex reduced the air-voids content and enhanced the hydrated products as a result of the pozzolanic reactions and latex effect. The adherence between the mortar and the porcelain tile was improved. Modolo et al. [29] aimed to investigate the bottom bed ash potential for being used as an alternative aggregate in cementitious-adhesive mortar by replacing commercial sand by an equivalent mass of 25, 50 and 100 wt% of bottom ash. The results of that study demonstrated that the replacement of coarse sand by bottom ash led to a decrease on water demand by formulations. Increasing the replacement amount of conventional sand by bottom ash proportionally increased the tensile adhesion strength of the formulations. Hwang et al. [30] studied the effect of polymer cement modifiers on mechanical and physical properties of polymer-modified and recycled artificial marble waste fine aggregate blended mortars. According to the obtained results, as the replacement ratio of artificial marble waste increased, the flexural strength as well as compressive strength decreased. Shao-jie et al. [31] investigated the usage of steel slag, iron tailings, and fly ash as aggregates in adhesive mortar. The effects of cement–aggregate ratio, polymer–cement ratio, and defoamer–cement ratio on performances of mortar were considered by authors. The polymer-modified waterproof mortar's performances including mechanical strength and impermeability pressure were improved compared to the ordinary cement mortar. It was also reported that, sand product cost can be reduced using iron tailings, steel slag and fly ash in case of river.

The correct combination of mineral powder, cement and polymeric emulsions may have synergistic effects of these three admixtures, by resulting in a construction material with a good performance for many applications. Therefore, the main purpose of the present study is by replacing the dolomite aggregate with waste marble powder in adhesive mortar, and to determine the appropriate ratio according to the values required by the relevant standards. Furthermore, at the cost of marble powder added insulation board mortar was analysed to determine whether the use of marble powder or dolomite raw materials was economical.

2. Material and method

2.1. Materials

2.1.1. Cement

In this study, Portland cement of type CEM I 42,5R was used as a binder and the specific gravity was 3.07 g/cm^3. Chemical properties are given in Table 1.

2.1.2. Marble powder (MP)

In order to be used in the experiments, "marble powder" was provided in powder form from a single type of marble block in a crusher plant that was crushed and sieved from Afyonkarahisar/Iscehisar region. The specific gravity of marble powder was 2.72 g/cm^3, chemical composition and grain distribution are presented in Tables 1 and 2, respectively.

2.1.3. Dolomite

In the experiments, raw dolomite material of 200–700 μm obtained from Eskisehir/Sivrihisar region was used. The specific gravity was 2.86 g/cm^3 and the hardness was 3.5–4 according to the Mohs scale. Chemical composition and grain distribution are shown in Tables 1 and 2, respectively.

2.1.4. Chemicals

In this study, various chemicals were used. These were cellulose, polymer, and starch which were in powder form and had the largest grain size of 90 μm. Due to the confidentiality principle of the supporter company's adhesive mortar design provided with the materials, detailed information about the properties of these materials could not be presented.

Table 1
Chemical analysis results of dolomite and marble powder (MP).

Component	Dolomite (%)	MP (%)	Cement (%)
SiO_2	0.12	0.63	20.68
CaO	57.4	54.70	63.57
Fe_2O_3	0.13	0.15	3.76
Al_2O_3	–	0.46	5.56
MgO	0.19	0.44	0.04
Cr_2O_3	0.06	–	–
BaO	0.25	–	–
SO_3	–	0.01	2.99
Na_2O	–	0.05	0.44
K_2O	–	0.05	1.06
MnO	–	0.04	–
SrO	–	0.02	–
L.O.I*	41.85	43.45	1.9

* Loss on Ignition.