Evaluation of Slip Potentials on Bilecik Beige Marble with Pendulum Method

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Abstract. This study deals with the determining of slip resistance and classification of slip potential for 5 different type of Bilecik Beige Marble were applied tumbling. TS EN 14231 Standard “Determination of Slip Resistance with Pendulum Friction Test Equipment” was basically utilized in determining the slip resistances of Bilecik Beige Marble with wet and dry surfaces. After tumbling process, by depending on the Bilecik Beige Marble type reduce slip potential, especially wet conditions. Slip resistance values on marble sample plates were specified to be considerably change by depending on both the applied surface processing techniques and dry/wet of surface characteristics. Finally, marbles used in this research have been classified according to safety applications by taking into account their slip resistance values.

1. Introduction
Present, natural stones are widely used as a flooring material in the housing sector and architecture. This usage in interiors, flooring and covering materials, bathroom and kitchen, and outdoors for stair coverings, paving, wall and floor covering material, is used as artistic sculptures and buildings. The most important parameter that should be taken into account in the use of marble for floor covering is slip resistance. Recently, slip resistance has become a serious issue in particularly floor covering designs. Slip resistance, caused by the interaction barefoot and / or are soles with the surface of the flooring material. Therefore, because people to be able to move safely, natural stone to be used as coating materials are needed to determine the shear strength [1-5]. Slip cases, one or more than one reason causes by contaminants, (water, oil, frost, dust) footwear and including features of the ground surface [6]. Anti-slip properties are directly affected surface process techniques [7].

In this study, investigated slipping potential of the pre-polished waste Bilecik beige marbles’ after and before tumbling process.

2. Materials and methods

2.1. Materials
Bilecik has very rich marble deposits. Because, extracted marbles is light colour, it called Bilecik beige marble. Therefore there are a lot of marble processing plant. The sample chosen waste marbles especially. Types of sample marble used in the experiments, code dimensions and surface process are given in Table 1.

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Table 1. Type and dimensions of the tested marbles.

| Sample Code | Types of Sample                  | Surface processing methods | Dimension (cm) |
|-------------|----------------------------------|-----------------------------|----------------|
| A1          | Rosalia Beige Bilecik             | Polish                      | 15x15x1        |
| A2          | Rosalia Light Bilecik             | Polish                      | 15x15x1        |
| A3          | King Crema Beige Bilecik          | Polish                      | 15x15x1        |
| A4          | Crema Nuova Beige Bilecik         | Polish                      | 15x15x1        |
| A5          | King Beige Bilecik                | Polish                      | 15x15x1        |

2.2. Method

In this study, investigated slipping potential of the pre-polished waste Bilecik beige marbles’ tumbling after and before process. Firstly, picked up 5 type Bilecik beige marble in waste area. Then, these samples are tested with pendulum test equipment, and determine pendulum slip value. Secondly, every sample 3 hours tumbled in tumbling test machine and tested with pendulum test equipment again. Every test applied dry and wet conditions and determine dry and wet slipping value.

2.2.1 Pendulum

The pendulum slip test was originally developed to simulate the action of a slipping foot. The method is based on a swing dummy heel, which sweeps over a specified area of flooring (just making contact with the surface) in a controlled manner. The slipperiness of the flooring has a direct influence on the pendulum value obtained (known as the Slip Resistance Value (SRV) or PSV (Pendulum Slip Value) with high CoF values slowing down the pendulum, reducing the distance it travels after contact with the test floor.

This is one of the preferred methods of test in the Turkey. Pendulum Slip Tester is simple to operate and said to demonstrate good correlation to real life conditions. The added benefit of full portability is essential in the evaluation of onsite slip potential. The pendulum test equipment shown in Figure 1.
The marbles slip resistance and slip potential classify according to Table 2 and Table 3. This classification demonstrate that, the marble slip class and usage area in construction.

**Table 2. Classification of slip resistance [8]**

| Pendulum Test Values | Slip Resistance |
|----------------------|-----------------|
| 0-24                 | High            |
| 24-34                | Moderate        |
| 34-64                | Low             |
| >65                  | Very Low        |

**Table 3. Classification of slip potential [8,9]**

| Class | Pendulum Test Values | Slip Potential | Application Areas                   |
|-------|----------------------|----------------|-------------------------------------|
| V     | >54                  | High           | Exterior Slopes                     |
|       |                      |                | The Outdoor Walkways,               |
|       |                      |                | Pool Surroundings,                  |
|       |                      |                | Outdoor Stairs                      |
|       |                      |                | Shopping Malls, Dining              |
| W     | 45-54                | Moderate       | Areas, Hotel Entrances,             |
|       |                      |                | Public Dressing Rooms               |
| X     | 35-44                | Low            | Bathroom, Storage Room,             |
|       |                      |                | Laundry                             |
| Y     | 25-34                |                 | Shopping Malls                      |
| Z     | <24                  | Very Low       |                                     |

2.2.2. Surface processing methods

In this study, pre-polished waste Bilecik beige marbles were processed only tumbling process. Tumbling is an abrasion processing which is a produced using abrasive for a pre-defined period of time. Marble pieces are put into the tumbling tub with water and abrasives (60 grits). As a result of various mechanical movements of the machine, the marble pieces are mixed with the abrasive–water mixture and then abrade. In the tub which produces vibration, beating and churning movements, marble pieces are processed with different forms of abrasives [10]. The marbles used in the study were tumbled in ERBA brand tanks which have a capacity of 1800 l and a maximum stone capacity of 60x90 cm (Fig. 2).
3. Results and discussions

The first sight and processed sight of marble samples is shown in Figure 3 and Figure 4. The polished marbles (Figure 3) corners sharp and surface is bright, but the tumbled marbles (Figure 4) corners annular and surface is mat.

![Figure 3. Polished Marble Sample](image1)

![Figure 4. Tumbled Marble Sample](image2)

As a result of experiments conducted polished Bilecik beige marble shown more shear potential than tumbled Bilecik beige marble in dry condition (Figure 5). Additionally, tumbled Bilecik beige marble shown more slip resistance than polished Bilecik beige marble in wet condition (figure 6). But, especially it was determined that the slip resistance of tumbled marble rather increase in wet conditions.

![Figure 5. Result of Pendulum Tests in Dry Condition](image3)

![Figure 6. Result of Pendulum Tests in Wet Condition](image4)

The sample of marbles slip resistance classified in Table 4. According to this data tumbled Bilecik beige marble can use as coating material in many places and any conditions. Tumbled Bilecik beige marble coating especially outdoor areas, such as outdoor walkways, pool surroundings, outdoor stairs. But, because of rather low level of slip resistance of polished marble, it is recommended this marble use indoors only.
Table 4. Dry and it in wet conditions classification of marble samples [9].

| Conditions and process | A1     | A2     | A3     | A4     | A5     |
|------------------------|--------|--------|--------|--------|--------|
|                        | PTV    | Class  | PTV    | Class  | PTV    | Class  | PTV    | Class  |
| Dry                    |        |        |        |        |        |        |        |        |
| Polished              | 30     | Y      | 33     | Y      | 40     | X      | 42     | X      | 38     | X      |
| Tumbled               | 65     | V      | 68     | V      | 72,5   | V      | 58     | V      | 61     | V      |
| Wet                    |        |        |        |        |        |        |        |        |        |
| Polished              | 5      | Z      | 5      | Z      | 0,5    | Z      | 6      | Z      | 1      | Z      |
| Tumbled               | 45     | W      | 42,5   | X      | 53     | W      | 41     | X      | 44,5   | W      |

4. Conclusions
As a result of these experimental studies have shown, the marble will be used as a flooring material, TS EN 14231 standards based, polished and tumbled surfaces with 5 different types of marble on the slip resistance values were determined. It is proposed experimental analysis of marbles slip resistance values determined which should use suitable areas. As expected, the slip potential is reduced in dry conditions due to a rise of the slip resistance on all surfaces. In wet conditions on all surfaces for slip resistance values reduces and potential and increases the risk of slipping. Tumbled Bilecik beige marble can use as coating material in many places and any conditions.

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