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# The Utilization of Marble and Cement Powder as Material for Highway Subgrade Soil Stabilization

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**Abstract.** The utilization of marble powder is not only as waste management but also can be used to increase the carrying capacity of the soil and reduce the amount of cement consumption in the lower foundation of the pavement structure that uses cement as a highway subgrade. To show the carrying capacity increase, this research conducted a laboratory experiment with chemical stabilization method. The additives used were 4% cement and marble powder with levels of 5.5%, 8.5%, and 11.5% of the dry weight of the soil. Mechanical testing was implemented using the California Bearing Ratio (CBR) test in the non-submerged condition. The highest value of CBR was 7.66% at 2.5 mm penetration which was found in the soil treated with cement and marble composition of 4% and 11.5%, respectively. This means that there is a significant increase in the CBR value, which is equal to 65.90% of the original soil CBR value.

## INTRODUCTION

Cement soil is a mixture of soil with cement which is then compacted to produce a new mixture of materials that has strength, characteristics, and resistance to weather changes. Therefore, it can be used as a sub-base layer of road pavement structures. The cementation reaction that occurs in the soil-cement mixture forms a new and harder granules that are stronger to withstand the given load [1]. Cement soil can be added with additives that function to reduce cement content and increase the bearing strength and durability of the resulting cement soil.

Marble waste is the residue from marble processing that come from the metamorphosis process or the conversion from limestone. This marble waste can be in the form of powder or small lumps. The content of this marble powder is Calcium Oxide (CaO) of 52.69% and other chemical elements [2,3]. Calcium Oxide (CaO) is the same element as the basic ingredient of Portland cement, so marble powder can be used as an alternative to soil mixture additives because the chemical elements in it are able to increase soil stability [4] and can reduce the amount of cement consumption.

Waste-based Soil stabilization has been done by many previous researchers. The use of Dry Dust Collector waste, silica sand waste and foundry sand waste as soil stabilization additive material can increase the bearing capacity of the soil [5,6].

In this study the stability of the soil with cement soil and marble powder using soil as a base material from the Bekasi area, West Java, Indonesia. The CBR value of the clay was 3.20% for a CBR of 2.5 inches [7] and the variation of cement used is 4%, whereas for the marble powder were 5.5%, 8.5% and 11.5%. The test to be carried out is the CBR (California Bearing Ratio) test. It is hoped that the addition of marble powder can increase the CBR value and reduce the use of the amount of cement.

## METHOD

This research is a laboratory experiments using the materials from Bekasi, West Java, Indonesia, i.e., a Portland type 1 cement (4% of the dry weight of the soil), and marble powder waste is in the form of white powder (taken from

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the Tulungagung, East Java, Indonesia). Marble powder is obtained from the results of cutting or carving marble rocks from Bintang Antik Sejahtera Group, located in Blumbang Village, Campurdarat District, Tulungagung Regency, East Java, Indonesia. Marble powder used as much as 4.5%, 8.5%, 11.5%. The main equipment used is the CBR test equipment, and the Proctor standard compaction test equipment. The tests were Plasticity Index, Specific Grafity, compaction, CBR on the original soil and soil mixed with cement and marble powder that had been cured (left at room temperature) for 7 days before physical and mechanical tests were carried out. To distinguish the levels of additives in each sample variant, a variation code was created as presented in Table 1.

**TABLE 1.** Additive levels in each sample variant

| N | Code* | Compound | |
|---|---|---|---|
| | | Cement (%) | Marmer Powder (%) |
| 1 | TA | 0 | 0 |
| 2 | $TS_4$ | 4 | 0 |
| 3 | $TM_{5.5}$ | 0 | 5.5 |
| 4 | $TM_{8.5}$ | 0 | 8.5 |
| 5 | $TM_{11.5}$ | 0 | 11.5 |
| 6 | $TS_4M_{5.5}$ | 4 | 5.5 |
| 7 | $TS_4M_{8.5}$ | 4 | 8.5 |
| 8 | $TS_4M_{11.5}$ | 4 | 11.5 |

*Code
- TA : Original Soil
- $TS_4$ : Soil + 4% cement.
- $TM_{5.5}$ : Soil + 5.5% marble powder.
- $TM_{8.5}$ : Soil + 8.5% marble powder.
- $TM_{11,5}$ : Soil + 11.5% marble powder.
- $TS_4M_{5.5}$ : Soil + 4% cement + 5.5% marble powder.
- $TS_4M_{8.5}$ : Soil + 4% cement + 8.5% marble powder.
- $TS_4M_{11.5}$ : Soil 4% cement + powder 11.5% marble.

## RESULTS AND DISCUSSION

The results are presented in Table 2 and Table 3. Analysis of the results is presented in Figure 1 and Figure 2.

### Result

Table 2 is the result of the original soil characteristics test. The results of the physical and mechanical properties of the original and mixed soils are presented in table 3.

**TABLE 2.** Value of Original Soil Characteristics

| Kind of Testing | Unit | Value |
|---|---|---|
| Soil density | - | 2.557 |
| Liquid limit | % | 58.9 |
| Plastic limit | % | 30 |
| Plasticity Index | - | 28.9 |
| Soil classification | - | CH |
| Dry weight (γd) | $kg/cm^3$ | 1.341 |
| Optimum water content | % | 31.51 |
| CBR 2.5 mm | % | 4.83 |
| CBR 5mm | % | 4.82 |

**TABLE 3.** Results of Physical and Mechanical Properties Tests for native and mixed soils

| Variation (code) | Additive (%) | | Spec. Gravity | Consistency Limit | | | Compression | | CBR | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cement | Marble | | Liquid limit | Plasticity limit | Plasticity index | OMC | MDD | 2.5mm | 5mm |
| | (%) | (%) | | (%) | (%) | (%) | (%) | (kg/cm$^3$) | (%) | (%) |
| TA | 0 | 0 | 2.557 | 58.9 | 30.0 | 28.9 | 31.51 | 1.341 | 4.83 | 4.82 |
| $TS_4$ | 4 | 0 | 2.572 | 61.5 | 34.8 | 26.7 | 32.39 | 1.320 | 6.63 | 7.01 |
| $TM_{5.5}$ | 0 | 5.5 | 2.520 | 58.9 | 28.1 | 30.8 | 29.81 | 1.363 | 5.06 | 5.24 |
| $TM_{8.5}$ | 0 | 8.5 | 2.543 | 55.7 | 28.7 | 26.9 | 30.94 | 1.364 | 4.56 | 4.77 |
| $TM_{11.5}$ | 0 | 11.5 | 2.516 | 55.0 | 25.7 | 29.2 | 31.58 | 1.339 | 4.96 | 4.97 |
| $TS_4M_{5.5}$ | 4 | 5.5 | 2.541 | 58.7 | 29.1 | 29.5 | 31.68 | 1.345 | 6.86 | 7.52 |
| $TS_4M_{8.5}$ | 4 | 8.5 | 2.549 | 60.8 | 31.9 | 28.9 | 30.23 | 1.352 | 7.52 | 7.79 |
| $TS_4M_{11.5}$ | 4 | 11.5 | 2.540 | 61.9 | 32.2 | 29.7 | 30.53 | 1.378 | 7.66 | 7.99 |

## Discussion

The CBR values for native and mixed soils are presented in Figure 1 and Figure 2. The CBR value was used to measure the bearing capacity, soil load, and pavement load [8]. The CBR value of 5 mm TA-variation penetration is 4.82%. In the road subgrade criteria, it is considered as a bad material because it is < 5%. The soil stabilized with marble powder without cement experienced a slight increase in CBR value from the original soil CBR value. This is in accordance with research [2,3]. The increase in CBR value occurred due to the cementation process because of the addition of marble powder content. Although slightly increased from the original soil, the CBR value found in marble powder without cement (Figure 1) is still below the road subgrade requirement (<5%) which means that the stabilized soil is not suitable for use as a road subgrade.

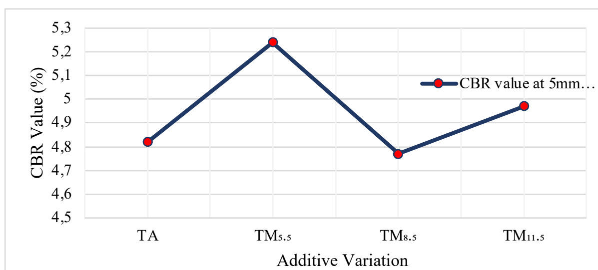


**FIGURE 1.** CBR value of soil without cement with the addition of marble powder content

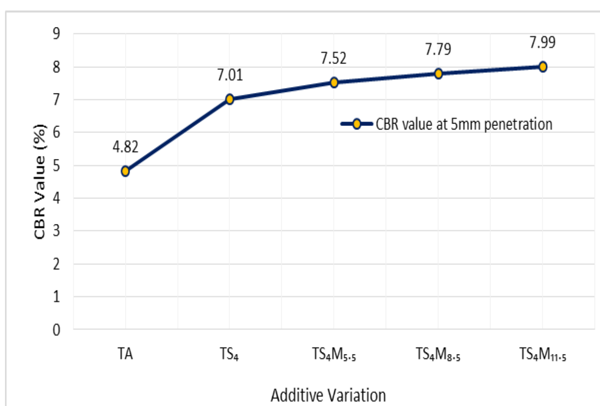


**FIGURE 2.** CBR value of cement-soil with the addition of marble powder content

The soil stabilized with cement and marble powder (figure 2) experienced a significant increase in the CBR value of the original soil CBR value. The CBR value in cement-soil continues to increase with increasing levels of marble powder applied. In the TS4 variation, the CBR value increased by 46.62% compared to the original soil CBR value. In the variation of TS4M5.5, there was an increase in the CBR value of 56.22% compared to the CBR value of the original soil at. Variation TS4SM8.5 showed an increase in CBR value of 61.75% to the original soil. It was found that the highest increase in CBR value was 65.90% of the original soil CBR value in the TS4M11.5 variation. The increase in CBR values in cement-soil and marble powder was due to the flocculation of clay particles with cement [1], while the presence of marble was sufficient to help the occurrence of cation exchange, pozzolanic reactions, and flocculation [4].

## CONCLUSION

The use of marble powder and cement waste as a soil stabilizing agent showed 65.90% CBR-value increase compared to the original soil CBR value; hence, it met the minimum CBR requirements for highway subgrades. It is necessary to conduct microstructural and chemical analysis research to see changes in the structure and texture of stabilizing soil to support the results of this study.

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