Application of Waste Rock Dust in Cement Binding Mixtures Used in Roadway

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Abstract. The article contains the results of research on the effect of waste rock dust on the properties of cement-bound mixtures. Gabbro-limestone dust with a significant proportion of active silica and calcium carbonate was used for the tests. The results of strength tests after 28 days of maturation with a variable proportion of cement (3\%, 5\%, 7\%) and rock dust (0\%, 10\%, 20\%) are presented. The stabilized aggregate was fine sand. The obtained results did not show the expected strength and frost resistance of the tested samples. The analysis of the results shows that the addition of rock dust is not applicable in dusty soils.

1. Introduction

Rock dust is a waste generated in aggregate mines during rock crushing and sorting of mineral aggregates used, among others, for the production of concrete. Similar dusty waste is produced in the technological process of producing the MMA asphalt mix. The disposal of this waste is a considerable problem. The interest in the use of waste materials is growing due to the increasing demand for aggregate in the construction industry.

During the grant implementation, research was carried out, which indicates that waste rock dust in the production of mortars and concrete can be used as a partial replacement for sand and even cement. According to [1, 2], waste dust seals the concrete structure, increasing its durability and positively affecting its strength. This type of waste can also be successfully used for soil stabilization [3]. It has been proven that waste rock dust has a positive effect on the properties of cohesive soils. Their addition increases their compressive strength [4, 5] and in the case of limestone waste, it reduces their swelling and deformability [6, 7].

In the case of soil stabilization with cement according to PN-EN 14227-1: 2013-10 and WT 5, it is allowed to use additives such as lime, fly ash, or calcium chloride. However, there is no information on the possibility of using waste material of rock origin.
The article presents the results of strength tests after 28 days of maturation of cement-bound mixtures with a variable proportion of waste rock dust.

2. Research material and research program

Dust waste produced in the technological process for producing the MMA mineral-asphalt mixture obtained from PBDiM KOBYLARNIA S.A. was used for the tests. These dusts were produced by grinding limestone and gabbro rocks. The particle size distribution curve of the dusts used is shown in Figure 1. The popular and commonly used CEM II / B-V 32.5R cement was used for stabilization.

![Particle size distribution curve](image)

**Figure 1.** The particle size distribution curve of the used dust

The aggregate used was fine sand from the Sikorowo mine, obtained thanks to the courtesy of GDDKiA in Bydgoszcz. Its grounding and the marked compaction parameters are presented in tables 1 and 2, respectively.

| SYMBOL | UOM | RESULTS |
|--------|-----|---------|
| The Uniformity Coefficient | Cu | - | 2,8 |
| Gravel fraction content | f_z | % | 1,5 |
| Sand fraction content | f_p | % | 89,3 |
| Dust fraction content | f_π+i | % | 9,3 |

**Table 1.** The grain size distribution of the used sand
Table 2. Determined compactability parameters of the used sand

| SYMBOL                | UOM     | RESULTS |
|-----------------------|---------|---------|
| Moisture content      | W_{opt} | %       | 15.1   |
| Maximum dry mass density | \rho_d | g/cm³   | 1.694  |

Figure 2. The particle size distribution curve of the tested sand together with the limit particle size distribution curves for CBGM 0/8 mixtures according to WT5

The test program is based on PN-EN 14227-1:2013, WT5 and PN-S-96012. Mixtures with variable amounts of cement and waste dust were designed. The unconfined compressive strength R_{28} [MPa] was determined after 28 days of curing. Cylindrical samples with a diameter of \( \Phi = 100 \) mm and \( \frac{H}{D} = 1.2 \) were used. The samples were formed with a Proctor mechanical compactor according to PN-EN 13286-50:2007. Figure 2 shows the particle size distribution curve of the sand used, placed between the grain size limit curves for CBGM 0/8 mixtures. The content of the finest fractions is exceeded in relation to the requirements for this type of mixtures according to WT5. Possibility of using waste material of rock origin.

Laboratory tests of the mixtures were carried out in the road laboratory of the GDDKiA in Bydgoszcz. Table 3 presents a simplified scope of the mixture strength tests with a different proportion of waste rock dust and cement.
Table 3. A simplified scope of sand mixtures strength tests

| CEMENT CONTENT | 3%  | 5%  | 7%  |
|----------------|-----|-----|-----|
| DUST CONTENT   | 0%  | 10% | 20% |
|                | Mixture 1 | Mixture 2 | Mixture 3 |
|                | Mixture 4 | Mixture 5 | Mixture 6 |
|                | Mixture 7 | Mixture 8 | Mixture 9 |

3. Results and discussions
The obtained values of unconfined compressive strength $R_{28}$ after 28 days are shown in figures 3-5 and in Tables 4-6. Determination method made in accordance with PN-EN 13286-41:2005.

In mixtures with the lowest cement content, the obtained compressive strengths, regardless of the share of waste dust, are low (figure 3 and table 4). Without the addition of dust, the compressive strength was 0.33 MPa, and for the dust content of 10 and 20%, it reached the strength of 0.23 MPa.

Figure 3. Average unconfined compressive strength results after 28 days of maturation $R_{28}$ at 3% cement content
Table 4. Unconfined compressive strength results after 28 days of maturation $R_{28}$ at 3% cement content

| DUST CONTENT | $R_{28}$ [MPa] |
|--------------|----------------|
| 0%           | 0.33           |
| 10%          | 0.22           |
| 20%          | 0.23           |

Compressive strength values for mixtures with a cement share of 5% are almost twice as high (figure 4 and table 5). For dust contents of 10 and 20%, the strength was 0.46 MPa and was about 23% lower than the mixture without waste dust.

Table 5. Unconfined compressive strength results after 28 days of maturation $R_{28}$ at 5% cement content

| DUST CONTENT | $R_{28}$ [MPa] |
|--------------|----------------|
| 0%           | 0.60           |
| 10%          | 0.49           |
| 20%          | 0.48           |

For the cement content of 7%, the differences in the strength values were much smaller and did not exceed 11%, but also in this case the samples without the addition of waste dust turned out to be the strongest – 0.89 MPa (figure 5 and table 6). Noteworthy is the higher compressive strength value of 0.81 MPa for mixtures with a dust share of 20% compared to 10%.
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### 4. Conclusions
The tested fine grained sand is difficult to stabilize with cement, even without waste rock dust. None of the mixtures achieved a satisfactory compressive strength and are not suitable for use in road construction. It should be noted that in the case of mixtures with a low cement content (3% and 5%), the addition of waste rock dust did not significantly reduce the compressive strength. In the case of mixtures with 7% cement content, increasing the content of waste rock dust to 20% had a positive effect on the strength of the mixtures in relation to their 10% content.

In the future, further tests with the use of waste rock dust should be performed, in particular for less dusty soils.
Acknowledgment(s)
This article/material has been supported by the Polish National Agency for Academic Exchange under Grant No. PPI/APM/2019/1/00003.

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