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Performance of Wire-Reinforced Gypsum Loaded in Compression

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Abstract. Recycled materials can be efficiently exploited in railway engineering, e.g. for soil reinforcement during the construction of the railway bed. These can be used in the form of binder, e.g. recycled cement from old concrete sleepers, or as subsoil reinforcement. For the purpose of experimental investigation and testing, gypsum has been chosen as a model material to test the dispersed reinforcement in the form of wires obtained by recycling old automobile tires. In particular, a response of the material to the mechanical loading was monitored in a series of uniaxial compression tests. The results indicate that such reinforcement can be efficiently used to improve the subsoil properties and significantly increase its ductility.

Introduction

The use of recycled materials in the construction industry is becoming extremely popular, especially with respect to the reduced price and environmental protection. For instance the railway construction is one of the branches in civil engineering with a huge potential for the exploitation of the recycled materials or waste and the current research is seeking for the new ways of recycling and maximization the efficiency [1, 2]. There are many possibilities of using the recycled material in the railway construction among which the soil stabilization in several bed layers [3] seems to be the most prospective. The stabilization can be accomplished by means of binder injection or addition of dispersed reinforcement [4, 5, 6]. Such reinforcement would lead to the improvement of the subsoil strength and stiffness. However, the following parameters must be met: a) the mass portion of the strengthening binder is usually between 1 to 4 %, related to the mass of dry soil [2, 3], b) for the stabilization of soil, the commonly used amount of the binding agent is about 3 to 15 %, which should provide the compressive strength ranging between 1.0 and 2.5 MPa (depending on the orientation and loading of the railway bed) [1].

Tested Samples and Experimental Methods

The presented study is dealing with an experimental testing of gypsum cylinders reinforced by recycled steel wires (or rather steel wool) produced in the recycling plant from old car tires. The wires act as a dispersed reinforcement increasing the load-bearing capacity, ductility and resistance to cycling loading of the gypsum samples loaded in compression [7, 8]. Non-reinforced gypsum samples exhibit a brittle failure when the compressive strength is exceeded, leading to an abrupt loss of their load-bearing capacity and destruction of the samples [9, 10]. The tested cylindrical specimens were 120-130 mm high and their base had a diameter of 100 mm. The matrix was produced from commonly available gray gypsum and the water to binder ratio was equal to 0.71.

There were three sets of samples, each represented by three specimens. The first (reference) set, denoted GS-I, was composed of the pure matrix without any reinforcement. The second set (GS-II) was reinforced by 350 g of recycled wires per specimen and the gypsum had to be compacted using shaking table, as well as in the case of the third set (GS-III), see Fig. 1. Only the compaction of the third set was carried out less carefully leading to a less condense matrix, with about 40 % of volume containing large voids. The specification of individual sets, measured stiffness, compressive strength and reached strain are summarized in Tab. 1. The tested samples were cured for 5 days in a common laboratory environment with temperature of 25 ± 3 °C and relative humidity of 50 ± 4%. The cylindrical specimens were tested in displacement-controlled compression with load cell of a capacity equal to 100 kN. The development of displacement and compressive force were continuously recorded during the testing.

Table 1. Specifications of the tested samples.

Set	Amount of gypsum [g]	Amount of wires [g]	Bulk density [kg/m^3]
GS-I	1000	none	1070 ± 4 %
GS-II	900	350	1273 ± 10 %
GS-III	566	350	857 ± 12 %

Experimental Results

The experimental results (the stress-strain diagrams in Fig. 2) are summarized in Fig. 3. The strain monitoring was limited by the measuring range, of the transducers used during the testing, since the deformation exceeded 25 mm (Fig. 1). The maximum deformations on G-II and G-III presented in Fig. 3 were evaluated using optical measurement using image analysis in the second cycle after unloading of the specimens and removal of the transducers. The obtained stress-strain diagrams presented in Fig. 2 show the same behavior of the unreinforced G-I samples and reinforced G-II samples in the initial loading period, only the compressive strength of G-II is slightly higher. However, the failure mechanism is completely different. The unreinforced gypsum exhibits a brittle failure, while the reinforced samples showed a significant ductility due to formation of smeared cracks instead of a complete destruction as in the case of unreinforced samples. Fig. 1 clearly demonstrates the cracking pattern on the tested samples. It is obvious that the plain (GS-I) samples suffered a brittle failure, resulting in huge localized cracks, leading to the complete loss of load-bearing capacity. The onset of cracking on the reinforced and carefully compacted samples (GS-II) was also clearly observed after exceeding the compressive strength but the redistribution of stresses prevented their localization. Therefore, the samples did not fail and retained their load-bearing capacity. Moreover, a further hardening of samples could be observed in the non-linear domain, leading to the considerable ductility.

Fig. 1. Compressed samples of the plain G-I (the first from the left) and reinforced samples G-II (the second from the left); typical samples G-II after testing (right).

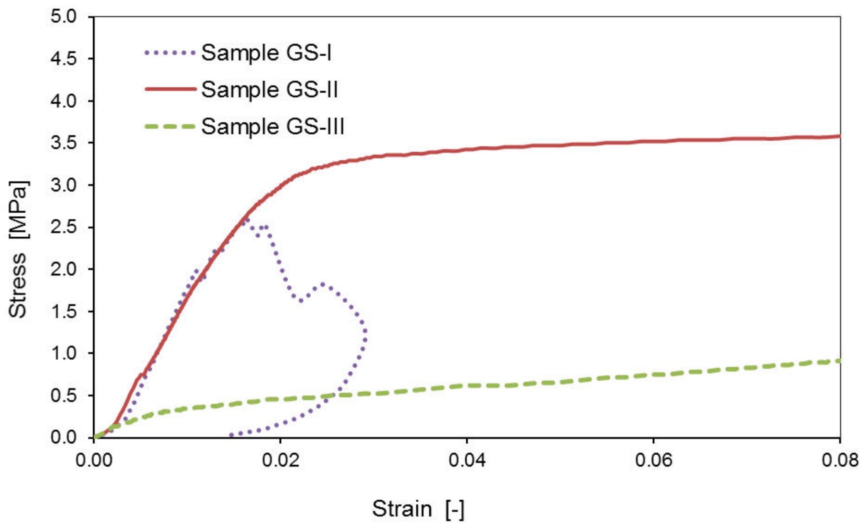

Fig. 2. Initial part of stress-strain curves typical for the plain and reinforced tested samples.

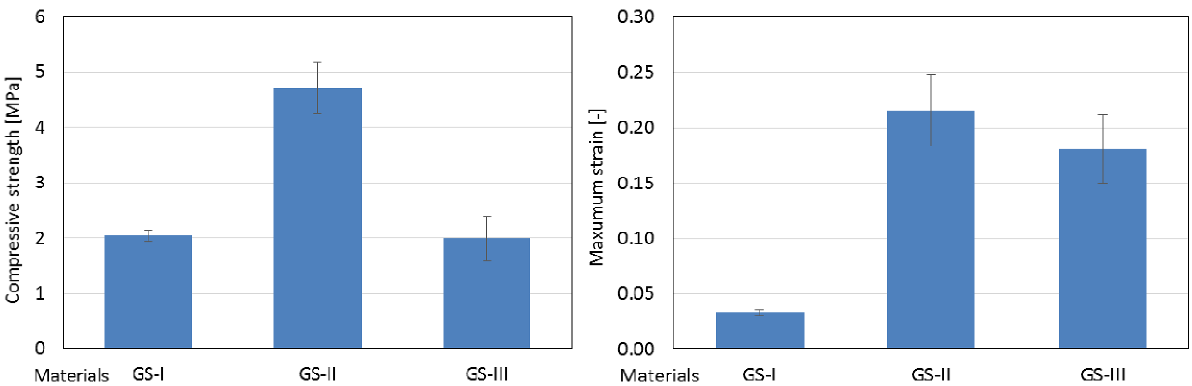

Fig. 3. Experimental results of the tested samples – compressive strength (left), maximum strain (right).

Conclusions

The obtained results of experimental testing demonstrate the huge potential of utilizing the wire reinforcement from old automobile tires. These can be exploited in the form of dispersed reinforcement used for stabilization of soil in railway construction. The presented study was carried out on gypsum, used as a model material. The analysis demonstrated the importance of a proper compaction, since the large voids present in the samples GS-III led to a localization of damage to the improperly compacted regions and limited load-bearing capacity.

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