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STRENGTH PROPERTY OF FUNCTIONAL CONCRETE MATERIAL AFTER CYCLIC STRESS

Abstract. This study investigated material properties of functional concrete materials, which were strained under cyclic stress test, including freezing and immersion in liquid solution. Two different functional concrete materials were studied, and the influence of compression strength before and after freezing and water immersion cycles was evaluated and discussed. Various properties between materials were recorded and the compression strength of functional materials were reduced 6.4 and 9.4%. The identified results demonstrate that the structure of concrete have influence on the durability of material in the strain of freeze-thaw cycling. A more durable material features ensure that the life cycle of products is longer, which reducing also stress on environment, making it more acceptable for utilization in various applications.

Key words: compressive strength, concrete, freeze-thaw cycling.

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ПРОЧНОСТНЫЕ СВОЙСТВА ФУНКЦИОНАЛЬНОГО БЕТОННОГО МАТЕРИАЛА ПОСЛЕ ЦИКЛИЧЕСКОЙ НАГРУЗКИ

Аннотация. Настоящая работа посвящена изучению свойств функциональных бетонных материалов, которые были подвергнуты испытанию на циклическую нагрузку, включая замерзание и погружение в жидкий раствор. Были изучены два различных функциональных бетонных материала, проведена оценка и сделаны выводы о влиянии прочности на сжатие до и после циклов замораживания и погружения в воду. Были зарегистрированы различные свойства материалов, прочность на сжатие функциональных материалов снизилась на 6,4 и 9,4 %. Полученные результаты показывают, что структура бетона влияет на долговечность материала при циклической нагрузке замораживания-оттаивания. Более прочный материал обеспечивает более длительный жизненный цикл продукции, что снижает нагрузку на окружающую среду и делает его более приемлемым для использования в различных областях.

Ключевые слова: прочность на сжатие, бетон, циклы замораживания-оттаивания.

1. Introduction

World economies are quite materials and energy intensive, demonstrating an increasing need for various materials. The demand of virgin materials is a remarkable, for example according to the publication of EPRS [1], 80 per cent of consumed materials in the European Union (EU) based on the substances that are pulled out of the earth. At same time, the life cycle of material is generally reduced, and materials become waste relatively quickly without any reuse option. It is reported that 94 per cent of virgin materials enter the waste stream within months [2]. These facts will create concerns for environment and resources.

The increasing awareness of the limited natural resources and environmental stresses were contributed researchers to develop sustainable products in the field of materials science. A circular economy is an economic system for production and consumption, based on the principle of sustainability. One strategy of circular economy is that the life cycle of products is extended [3]. In other words, it is essential to improve material so that its life cycle is so long-lasting as possible when total annual greenhouse gas emissions will be reduced. Concrete is a certain example of long-lasting material, which can stand on form as a long time in the correct circumstance [4]. Therefore, concrete has also a remarkable impact on the CO_2 emissions of materials. According to the study of Habert et al. [5], high performance concrete can allow for a 50% reduction in greenhouse gas emissions and, it is essential to develop material in order that its life cycle is so long as possible, especially while raw materials use is estimated to double by 2060 [6]. In addition, the development of material is justified because better quality material reduces maintenance costs. In this study, the durability features of concrete-like polymineral material was assessed.

A certain factor that will influence on the life cycle is a stress caused by weathering. The resistance of photo-oxidation, as well as freezing and thawing actions, are actual issues for materials in Northern Hemisphere, and especially in the Nordic areas. The previous mentioned weathering caused stresses can be analyzed by artificial weathering and freeze-thaw tests. The testing confirm that material will perform reliably and simulate it in many different real-world conditions. The frost resistance of concrete is generally determined in the laboratory with various cycles of freezing and thawing in water and or air, in the temperature range of (+4) – (-20) °C [7].

The main objective of this study is to evaluate the effect of freeze-thaw cycles on the strength property of concrete-like polymineral material. The recording of load amount and compressive strength property are used for the detection possible material changes.

2. Materials and Methods

Two various concrete materials were studied with compressive strength test after frost stress.

○ The material samples for testing were produced with forced concrete mixer, for maximum mixing quality.

○ Concrete materials were manufactured according to the standards GOST 7473-94 Concrete mixtures. Specifications and GOST 25820-83 Light concretes. Technical conditions.

○ P-samples with target density 1800 kg/m^3 and polymineral binder Organosilicon liquid-1 (impregnating).

○ G-samples with target density 2000 kg/m^3 and polymineral binder Organosilicon liquid-1

Altogether 24 samples were manufactured, 12 samples per material composition and including six reference samples and six samples. Each sample was cube-shaped, with a dimension of 100x100x100 mm.

Figure 1. Examples of investigated materials, P-sample (left) and G-sample (right)

Frost resistance of material was performed according to the standard of GOST 10060-2012 and third method. The third method includes saturation, freezing, and thawing conditions with the following parameters;

Figure 2. Hydraulic stress equipment, PSU-50A in 25-ton mode

5% aqueous solution of NaCl, 5% aqueous solution of NaCl at -50°C, 5% aqueous solution of NaCl at +20°C, respectively. Four and five cycles of freezing and thawing with artificial aging was performed, and duration of each cycle was one day. Test equipment in frost resistance test was climate chamber CM-55/50-120, which temperature ability varied between -80 – 250°C degrees.

The strength properties of studied materials were carried put compression strength test by using hydraulic stress equipment, PSU-50A in 25-ton mode. The compression strength was performed according to the standard of GOST 10180-2012 «Concretes. Methods for strength determination using reference specimens».

3. Results and Discussion

The strength feature of studied materials was assessed by the test of compressive strength. The compressive strength test illustrates the maximum amount of compressive load for material before fracturing. A test sample is in the form of a cube, which were compressed between the plates of testing machine. The material properties, including strength property, after freezing cycle tests are presented as a clustered column in Figure 3 and Figure 4.

Average breaking load for P- and G-sample before freezing exposure were 348.6 and 461.9 kN, respectively, with low values of standard deviations, 14.8 and 10.9. After the freezing exposure, the corresponding values were 326.9 and 416.9 kN, indicating weakening effect on the material due to the exposure. The standard deviation value for P-sample was congruent like before freezing exposure (SD 13.9) but with G-sample, standard deviation was increased, and it was 31.8. It can be assumed, that after freezing exposure, material is more heterogenous.

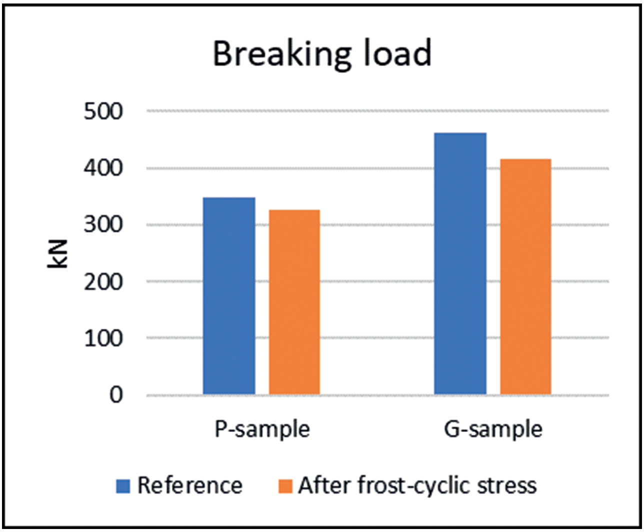

Figure 3. The maximum load amount of the studied materials before and after frost-cyclic stress

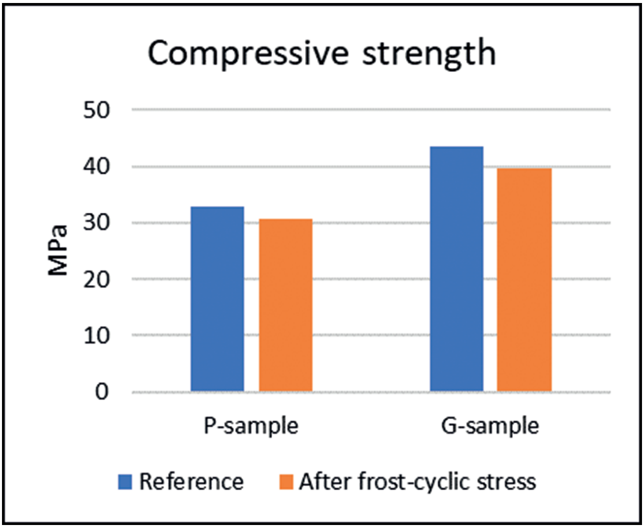

Figure 4 . Compressive properties of the studied materials before and after frost-cyclic stress

Average compressive strength values of P- and G-sample were 32.8 and 43.6 MPa, respectively, with minor SD values, 1.7 and 0.9, respectively. The exposure of freezing cycle reduced compressive strength properties, which were P- and G-sample 30.7 and 39.5 MPa, respectively. The standard deviations values were for P- and G-sample 1.2 and 2.9, respectively. Load and compressive strength are congruent between each other, ensuring the reliability of study calculations. The results showed that strength loss after frost-cyclic stress was 6.4%. The corresponding strength loss with G-samples was 9.4%.

During the test procedure of freezing cycles, sample's dimensions (length, width and height) and weight were measured. Therefore, the mass amounts before and after frost-cyclic stress were recorded, and mass losses of materials were calculated. The mass loss of G-sample was about 2%, while with P-sample, no significant mass loss was observed.

Unambiguous explanation is challenging for the material properties of concrete because generally, several variables may influence on the quality of concrete, such as material variability, process variation and mix-composition variability. Water content and its inconstancy is key variability reason for material but also production characteristics might have effects, like temperature, loading sequence or mixing time [8]. It is important to improve life cycle time of concrete because it is the most widely used man-made material, which consumes a lot of resources on planet, such as water [9].

Density measurement could be an indicator for strength properties because usually, it has linear correlation with the mechanical features. High density often indicates a solid and good microstructure of a material. In future, other weathering effects on material should be studied, such as the effect of sunlight, rain and biological degradation. In general, weathering effects decrease the material properties and usability, but it could be informative to know what is those effect on the concrete-like polymineral material. If those influence could be a dramatical, material properties might be improved by additives, such as ultraviolet absorbers (UVA) and hindered amine light stabilizers (HALS).

4. Conclusion

The effect of freezing cycles on the material properties of functional concrete materials was investigated in this study. Awareness of the features of functional concrete may allow its utilization in wider applications and make it more acceptable for various applications.

The results show that density correlate positively with the assessed strength properties. In addition, the frost-cyclic stress caused a slight decrease in the material properties of functional concrete and its quality includes more deviation. However, the erosion of material was quite insignificant consequently the studied functional concrete is feasible material also in areas where weathering conditions varies during the year. Some additives in material structure might improve the quality of concrete, which should be investigated in further research. In ideal case, concrete product can be reused as a structural element in novel applications, while improving local markets for re-use of structural segment.

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