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EXPERIMENTAL OF VERIFICATION OF ALTERNATIVE HYDRAULIC BINDERS FLEXURAL AND COMPRESSIVE STRENGTH

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Abstract. The paper deals with the investigation of alternative binders, namely the two available samples N6 and N7 with comparison from the reference sample CEM I 42.5R. Both testing binders are provided by company Destro. It is a product that contains different ratios of fly ash and slag. By examining the properties, the mix was compared in different proportions and subsequently tested for flexural strength and compressive strength. The results showed the effect of curing time and cement to binder ratio after 28 and 84 days.

Keywords: Alternative binder, fly ash, cement pastes, compressive strength, flexural strength.

1. Introduction

Nowadays, the use of alternative binders is becoming more and more popular in the construction industry as a replacement for cement. The use is more mainstream among the main objectives is to reduce CO_2 emissions that are produced in the production of cement with the high energy requirement for the creation. Individual introduction to alternative binders such as fly ash, which can be characterized as a fine-grained powder with a glassy structure that is produced as a waste material from the combustion of anthracite, lignite, and hard coal, where it is captured from the resulting gases by electrostatic or mechanical separators. Due to the numerous production processes using different types of boilers, combustion techniques, separation methods, and types of coal burned, the resulting ash can have quite variable chemical, mineralogical, and granulometric compositions. In the concrete industry, more use is made of fly ash produced from hard coal, as it is not as variable as brown coal fly ash. Slag is a coarse-grained substance of black to gray shade that may be of natural origin, i.e., volcanic or a product of the metallurgical industry, where it is produced as a waste product of iron or steel production. Previous scientific findings with the implementation of alternative concepts have shown promising results as described by A. Mohamed in his scientific work, where he observes the evolution of strength and rapid reactivity of the slag, where the results of the S1F1 (composed of slag and fly ash in a 50/50 ratio) pattern obtained remarkable results [1], A closer scientific evaluation is described by the scientific work of V. Shobeiri., where it relies on minimization of GWP (global warming potential) in concrete and replacement of SCM (supplied cementitios material) depending on OPC (ordinary portland cement) by supplementary materials [2]. Unfortunately, experimental methods require extensive experimentation and archiving so that we can meet the Paris Agreement on CO_2 reduction, and these experiments are often on a trial-and-error [3]. The experiment deals with selected N6 and N7 binders from different suppliers as replacement cement:

(1.) Binder N6 – Destrocement (fly ash),

(2.) Binder N7 – Destrocement (slag and fly ash).

Another reason is the cost per mix and the approximation of the same or better properties to Portland concrete at a reduced price due to alternative binders that can be recovered from recycled material or incorporated as waste material. Subsequently, the use of this waste material significantly reduces the price of the mix.

2. Materials and samples

The test specimens with dimensions $40 \times 40 \times 160$ mm were manufactured according to EN 196-1 [4], using moulds. A total of 5 mixtures were created for testing purposes, and 6 specimens were created for each mixture. The total number of specimens produced was 30.

The actual production of the sample consisted of weighing the necessary raw materials in the given ratio of water, cement, and fine aggregate 0/2 and crushed slag in a laboratory balance with an accuracy of ± 1 g, which can be seen in the Table 1. For all formulations, a water coefficient of 0.718 was established and the workability of the fresh mix was measured, using a cone spill after 15 blows. After the raw materials were weighed, the individual materials were added to the mixing vessel. First cement with an alternative

Marking	CEM I 42.5R [kg]	Destrocement (fly ash) [kg]	Destrocement R [kg]	Fine aggregate (0/2 mm) [kg]	Water [kg]
REF	0.825	-	-	2.475	0.592
N6 30	0.578	0.248	-	2.475	0.592
N6 50	0.413	0.413	-	2.475	0.592
N7 30	0.578	-	0.248	2.475	0.592
N7 50	0.413	-	0.413	2.475	0.592

Table 1. Overview of mixtures.

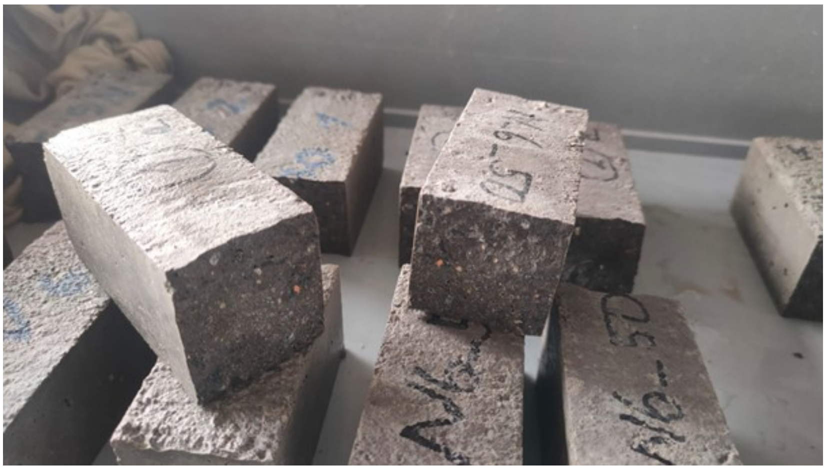

Figure 1. Detail of sample after destructive test.

binder due to mixing and losses. The third ingredient was water and the last was fine aggregate 0/2 and crushed slag. After all the ingredients were mixed, the material was filled into molds that were greased with a layer of forming oil for better removal of the sample after hardening. Immediately after the mixing was completed, the prepared steel triforms were filled about halfway with mortar using a spatula and the inner surface was painted with a thin layer of mineral oil. This first layer of mortar was further compacted. Finally, the mortar surface was aligned with the edges of the triforms using a spatula sawing motion and the samples were stored at an ambient temperature of 21 ± 2 °C. After expiration of the time, the samples were and removed from the molds followed by marking the sample and placing it in a water bath at 20 ± 5 °C until testing time. Storage was carried out for half of the samples for 28 days and the other half for 84 days.

3. Experimental methods

The experiment was tested for flexural strength on the basis of EN 196-1 [4], on specimens of $40 \times 40 \times 160$ mm beams. After measuring and weighing, the specimen was placed on two hydraulic press supports spaced 100 mm apart. Using the software, the measurement was started by moving the hydraulic press at a speed of 1 mm min^{-1} until the specimen was destroyed into two parts, which were further used for compressive strength measurements according to EN 196-1 [4]. Figure 1 shows the result after destructive testing, the main indicator being the resulting fracture and visible structure of the recycled compound used. This method investigated the introduction of compressive stress up to the time of specimen destruction. The specimen was used from the remaining two parts of the previous flexural strength test using a three-point arrangement. The body of the specimen was placed on the compression of the 40×40 mm machine. Then the hydraulic press displacement was started by the upper part displacement being constant throughout the test.

4. Results and discussion

The consistencies of the different mixtures in Figure 2 show us that as the cement values decrease, the spillage decreases. In Figure 3, we can see the bulk mass of each sample, which shows us the minimum variation with respect to the pore filling. From the measurements of the experiment using the three-point loading method to measure the flexural strength of the test specimens after a period of 28 and 84 days, the values shown in the Figure 4. The graph shows the strength range compared to the reference sample. The lower the cement content of the sample, the strength decreases. Interestingly, the destructiveness values at 50 % were like those of the reference sample after 84 days. For the N7 mixture, these values are even identical in strength at 30 % and 50 % of the mixture. For Fly ash N6 the reaction was confirmed after a longer curing time. Samples were tested using the uniaxial test after three points of testing. The highest and lowest compressive strength values were removed

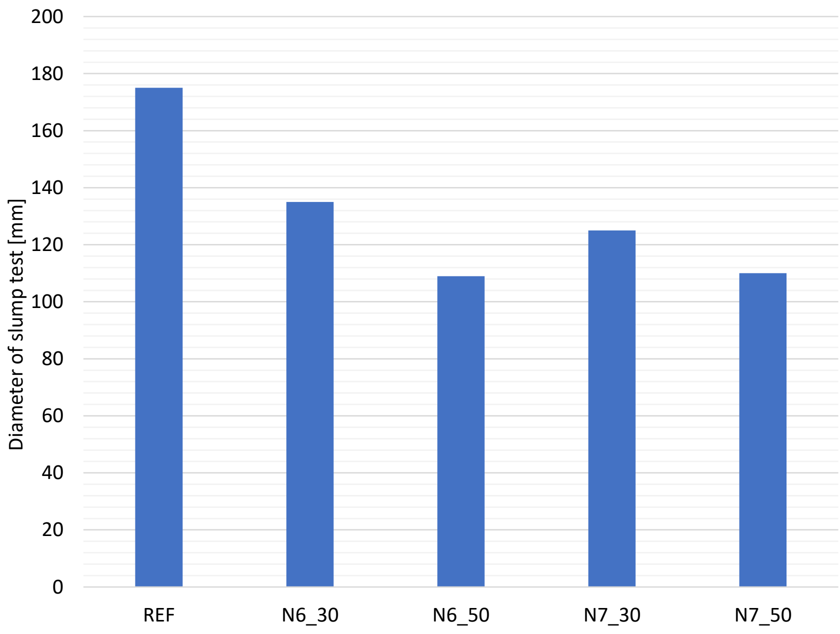

FIGURE 2. Spilling fresh mixture.

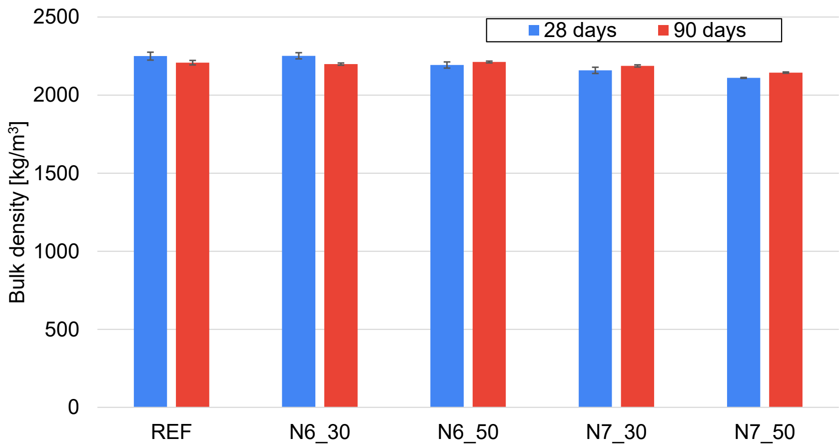

FIGURE 3. Bulk density of testing speciement with plotted standard deviations.

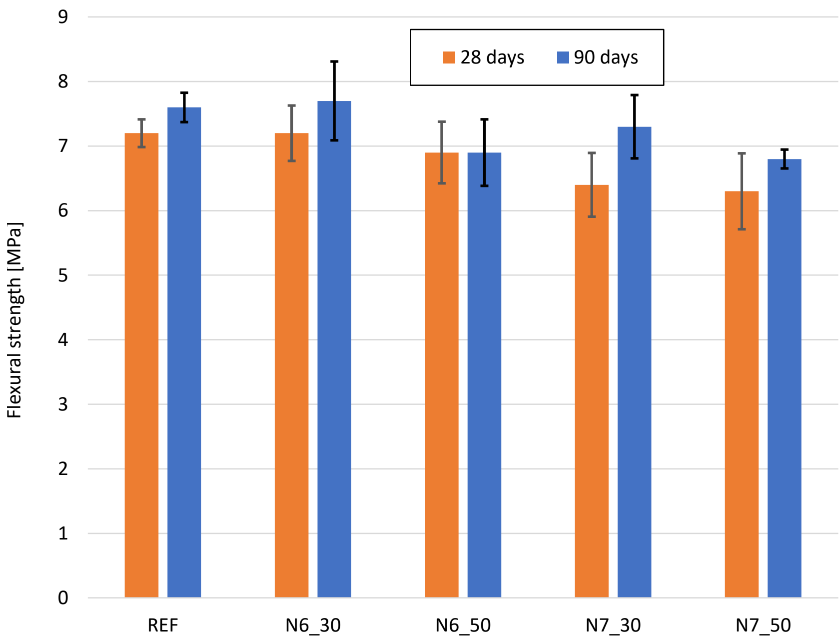

FIGURE 4. Flexural strength with plotted standard deviations.

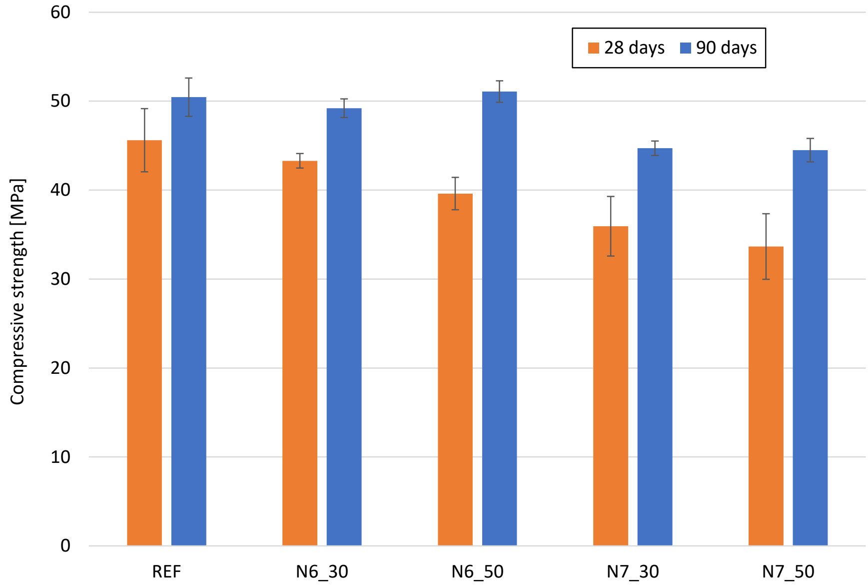

Figure 5. Compressive strength with plotted standard deviations.

from the obtained values and the arithmetic mean was removed from the remaining values, which can be seen in Figure 5. The result shows how the solidification time affects the strength of the samples and after 84 days the strength approaches the reference values. It is remarkable that for specimens N6 50 and N6 30 the values after 84 days are close. Similarly, for specimens N7 30 and N7 50 after 84 days, the values are in little difference.

Historically, although many studies have been conducted to quantify the effect of alternative binders on mechanical properties in concrete, the results were in mass agreement and had similar results. When alternative binders are applied as a partial replacement for CEM I, 42.5R materials such as slag and fly ash respond best after a longer curing time and therefore a higher strength increase can be observed after 90 days or more. Another factor affecting the individual mixes is the increase in the specific surface area due to the fineness of the material [5–7].

5. Conclusion

This work focuses on the effect of waste supplementary cementitious materials on the mechanical properties of cement pastes. Cement pastes are composed of mixed cement, where suplementary cementitious materials replaces Portland clinker. In our case, we used fly ash and slag. Supplementary cementitious materials were used in two different concentrations, namely: 30 wt. % and 50 wt. %. For our testing, the values for specimens N6 50 came out best in terms of replacement and applicability of alternative binders. For better observation and evaluation of the result, the curing time is a priority, which has a great influence on the properties of the different mixtures. A positive indicator is the reduction of hydration heat, which can be positively utilized. However, among the unpredictable factors in the application of an alternative binder, it is important to understand the origin of the material a qestion will be. Where the material was used, the method by which it was recycled and shredded, and the storage of the material. The aforementioned factors have implications for unforeseen admixtures that were not included. Therefore, it is worthwhile to establish a prescription for each future material to be recycled before use and recycling, so that it is appropriate for approximate laboratory conditions.

Considering all the results, the material can be used for construction works of a small nature, small weirs, walls, where the load is mainly caused by natural influences and high loads are not expected. The main limiting factor is the failure to guarantee the same properties of the alternative binder.

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