Evaluating the drying effect on the behavior of earth concrete using acoustic emission technique

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RESUME The requirement for eco-friendly construction materials is of a persistent need. In addition, waste recycling is urgent. The ecological material adopted in this study is earth concrete incorporated with recycled sand (RS). Both materials being sensitive to water, the work assesses the effect of drying on the mechanical properties. Earth concrete mixtures with different percentages of clay (20%, 30% and 40%) were casted and cured at a relative humidity (RH) of 90% and 50%. Compressive tests were conducted on cubic specimens for each mixture. Moreover, the acoustic emission (AE) technique was used to monitor the failure behavior of specimens conserved at the two RH. The results show an increase in the compressive strength at 50% of RH. However, a decrease in the flexural strength has been observed at 50% of RH with RS.

Mots-clefs earth concrete; drying; mechanical properties; acoustic emission technique

I. INTRODUCTION

The use of environmentally friendly materials in the construction field is a necessity nowadays (Kouta et al., 2020a). In this study, two environmentally friendly aspects are considered by proposing a pourable earth concrete made with local soil and RS. During their service life, construction materials are exposed to mechanical, thermal, drying and chemical stresses. This work assesses the effect of drying on the mechanical properties of earth concrete made with RS. As a result of drying, some studies reported an increase in concrete's strength which was attributed to capillary pressure while others stated a decrease in strength due to the formation of microcracks (Ngo et al., 2020; Soleilhet et al., 2017). The latter is attributed to the fact that when the material dries, it shrinks. If shrinkage is restrained (internally or externally), tensile stresses are generated which may induce micro-cracking when stresses are higher than the tensile strength. The objective of this paper is to study the effect of drying on the mechanical properties of earth concrete. For this, compressive tests were conducted on cubic specimens conserved in two curing conditions at 50% and 90% of relative humidity (RH). The compressive tests have been also monitored with the AE technique. The AE technique has been widely used in the field of civil engineering. It is a passive method that allows a continuous monitoring of damage evolution under loading (Kouta et al., 2020b; Saliba and Mezhoud, 2019).

First, the materials and experimental procedures are presented. Then, the mechanical properties of earth concrete under different curing conditions are displayed. Finally, AE results are shown.

II. Materials and Experiment

A. Materials

The work considers the mix of the average proportion 30/70 (30% clay and 70% sand – by mass -) as a reference mixture comprising only natural sand (NS). On the other hand, three other mixes of 20/80, 30/70 and 40/60 were prepared with 100% of RS. 80% pre-saturation of RS is considered to all mixes. Dry components were first introduced into a blender and mixed for 5 min in order to obtain a homogeneous mixture. Then, water was progressively added to ensure a slump value between 7 and 10 cm for all the mixes.

A non-swelling clay Kaolinite is used. Tests display a liquid limit and a plastic limit of 52.84% and 32.81% respectively. NS and RS reported water absorption value of 1.02% and 14.6%, respectively. 9% (of clay + aggregate mass) of cement (CEM 1, 52.5 N PM-CP2/ NF EN197-1) is added for strength and durability purposes. The superplasticizer Tempo 10 is also used as a water reducing admixture.

B. Experimental procedure

Prism specimens were casted in 4x4x16 cm^3 molds for flexure tests (3 specimens for each mixture). The used machine generates a maximum load of 204 KN. Speed was calibrated at 0.5 KN/s. For compressive tests, specimens were casted in 10x10x10 cm^3 molds (2 specimens for each mixture). An electro-mechanical machine with a capacity of 100 KN was used. The speed was modified at 2 different positions in the post peak region to reduce the experiment time. The speed values are: 0.5 mm/min, 1.5 mm/min and 4.5 mm/min. For all mixtures, demolding was done after 3 days of casting and cured at a relative humidity of 90% and 50%. As the ideal humidity for a house should generally be between 40 and 60%, a relative humidity of 50% has been adopted for drying conditions.

Compressive tests were monitored in parallel with the acoustic emission technique. The AEWIN acquisition system with a data analysis and storage system was used. 8 R15 piezoelectric sensors were placed on two opposite sides of the specimens using a thin layer of silicone to ensure a good coupling as shown in figure 1. The detected signals were amplified with a 40 dB differential amplifier. The detection threshold was set at 33 dB to avoid the effect of environment noise. Furthermore, the displacement was determined by adding a marker at each loading plate recording the change in distance upon loading.

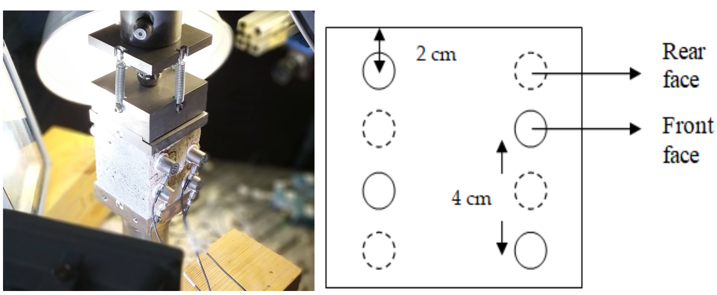

FIGURE 1. Experimental procedure and AE sensors positions

III. RESULTS AND DISCUSSION

A. Mechanical properties

The stress strain curves of the compressive tests conducted at the age of 28 days are presented in figure 2 (a). The pre-loading phase was eliminated to better demonstrate the elastic phase. The compressive strength, modulus of elasticity and flexural strength are presented in figure 2 (b, c, d) respectively. The compressive strength decreases with the clay percentage. Taking into account the mixtures of same formula NS30/70 and RS30/70, a decrease in modulus of elasticity, flexural and compressive strengths occurred as NS was replaced by RS. The demonstration of lower mechanical properties when RS is introduced is due to the fact that- as in classical concrete- more water is needed to compensate the loss in workability due to high water absorption of RS leading to a decrease in strength. Furthermore, the porous mortar attached to RS weakens earth concrete. Drying increased the compressive strength of all mixtures. This could be associated to the suction effect. In fact, the compressive strength depends on the attractive forces between the soil particles and water molecules. During shrinkage, strain pulls clay minerals closer which can increase the compressive strength when soil particles are in direct contact. However, the flexural strength reported a decrease in RS mixtures and an increase in the NS mixture due to drying. This may be related to a higher shrinkage rate and micro-cracking related to stress induced by desiccation and to a lower interfacial transition zone (ITZ) properties with RS. Furthermore, the modulus of elasticity increased for NS mixture and decreases with the % of clay with RS mixtures. A future work will examine the elastic phase by conducting cyclic loading tests.

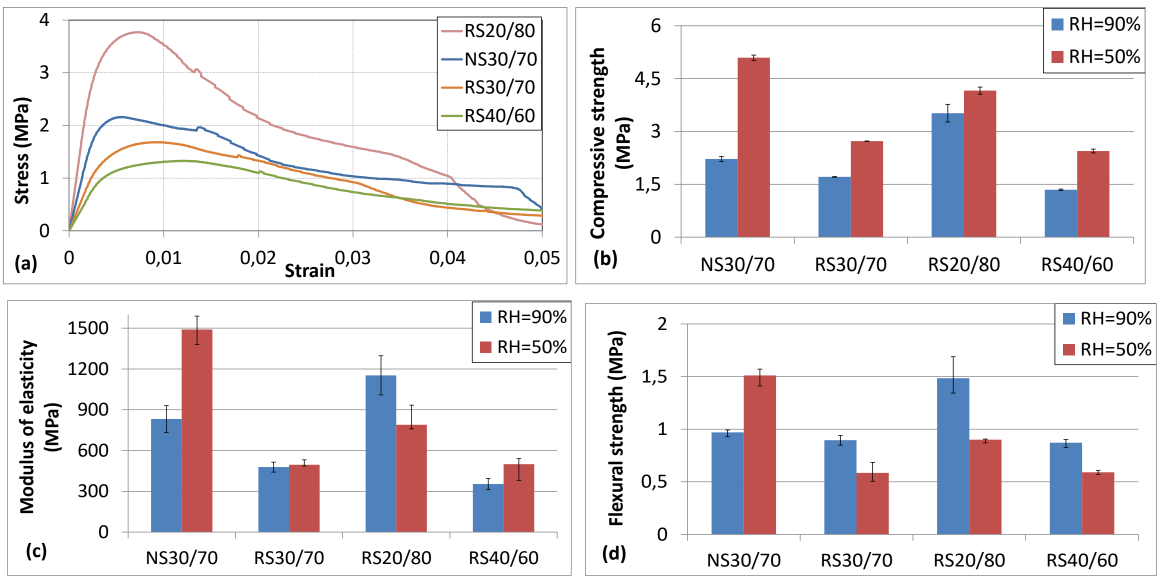

FIGURE 2. (a) Stress strain curves at a RH of 90% (b) compressive strength (c) modulus of elasticity and (d) flexural strength of earth concrete mixtures conserved in two curing conditions

B. Acoustic emission

Figure 3 shows the distribtion of AE hits in correlation with stress curves. Four zones can be distinguisged. The first stage is related to friction at the contact with metallic plate. The second shows a constant increase of a diffuse damage accompagned with few AE hits. The third indicates the propagation of macrocracks with an important rate of energetic AE hits and finally the fourth the stable propagation of cracks. The comparison of AE activity between specimens subjected to a RH of 50% and 90% shows a higher distribution of AE hits in the first and second stage. This can be attributed to shrinkage induced cracking. Such microcracking were directly induced at low stress levels. This may be also responsible of the higher brittleness observed in the post peak region.

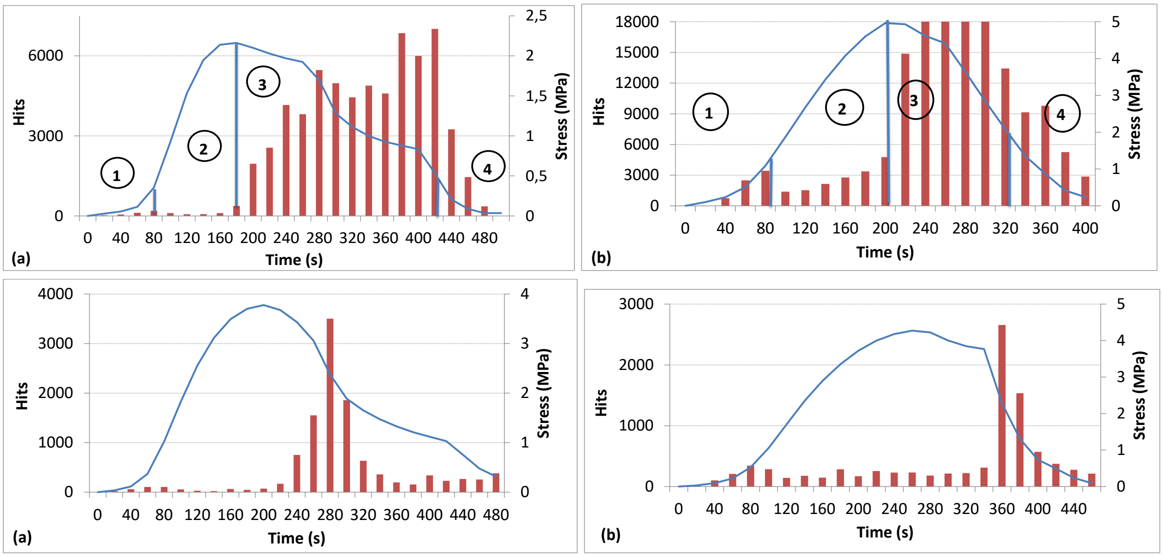

FIGURE 3. Correlation between the stress and the distribution of AE hits for NS30/70 and RS20/80 at (a) RH=90% and (b) RH=50%

IV. CONCLUSIONS

The effect of drying on the mechanical properties of earth concrete incorporating RS has been studied in this paper. The results show a decrease in the compressive strength with the clay percentage and the replacement of NS by RS. An increase in the compressive strength has been observed for specimens conserved at 50% of RH in comparison with those conserved at 90% of RH. The monitoring of the compressive tests with the AE technique reflected the microcracking generated by restrained shrinkage. This can also explain the decrease of the flexural strength with mixtures made with RS. Shrinkage tests will be conducted in the future for a better analysis of the results.

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