An attempt to estimate the fulfillment of Kaiser Effect in earth concrete mixtures

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RESUME The ecological material in this study comprises earth concrete made with recycled sand (RS). Three mixtures contain 20%, 30% and 40% of clay in addition to RS and one mixture of 30% of clay and natural sand (NS) were prepared. The specimens were exposed for 28 days to a relative humidity of RH=90% and RH=50%. Uniaxial compression cyclic tests were carried out. This study presents the correlation of stress and acoustic emission (AE) activity in the pre-peak phase of each mixture. It is an attempt to assess the attainment of Kaiser Effect at different stress levels and different curing conditions. The results show that at RH=90%, all mixtures attained or at least were not far from attaining Kaiser Effect. However, at RH=50%, as a result of shrinkage induced cracking, Kaiser effect was not fulfilled. Interestingly, the mixture with higher clay content showed remarkable increase in AEs at dried conditions compared to its state at RH=90%.

Mots-clefs Kaiser Effect, cyclic loadings, earth concrete, acoustic emission

I. INTRODUCTION

In the line with sustainable construction that demands the harmony between economic, environmental and social features, earth construction comprises the three aspects. It is of low cost, limits energy consumption and reusable. Moreover, it plays a significant role in terms of moisture buffering and temperature control.

Among different NDTs, the acoustic emission (AE) technique is evidenced to yield satisfactory results. Analysis is carried out based on the output parameters. Most importantly, these parameters and others are often used to classify the cracking mode or fracture mechanisms (Saliba and Mezhoud, 2019) and to assess damage.

The degree of damage can be assessed based on Kaiser Effect phenomenon. This phenomenon states that if a material got loaded, unloaded and then reloaded, AE activity (AEs) will not be generated until the previous maximum load (PML) is surpassed or exceeded. Nevertheless, if damage occurs before PML, Kaiser Effect is not satisfied and thus the ongoing assessment takes the name of Felicity Ratio (FR).

In the following work, after presenting the materials and experimental procedure, the correlation of stress and AE activity are displayed for each mixture at different stress levels and different curing conditions.

II. MATERIALS AND EXPERIMENTAL PROCEDURE

A. Materials

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 a water absorption value of 1.02% and 14.6%, respectively. Cement was added to be able to remove the formwork board at early age and for strength and durability purposes. A value of 9% of dry solid mass (clay + aggregate) has been considered (CEM 1, 52.5 N PM-CP2/ NF EN197-1). The superplasticizer Tempo 10 is used as a water reducing admixture. The work considers the mix with 30% of clay (by mass) and 70% of natural sand (NS) as a reference mixture. On the other hand, three other mixes of 20/80, 30/70 and 40/60 were prepared with 100% of recycled sand (RS). 80% pre-saturation of RS is considered to all mixes avoiding the dry state that would exhibit a slump loss with time and the saturated state that would show a decrease in strength due to water flow outside RS. 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.

B. Experimental procedure

10 cm3 were casted in wood molds, demolded then after 3 days to be conserved at a 90% and 50% relative humidity (RH=90% and RH=50%) environments. A 50% relative humidity is in the range of the ideal relative humidity of a house. Compression tests were carried out on specimens after 28 days of casting using electro-mechanical machine with a 100 KN capacity. Based on the two simple compression tests done for each mixture, the cyclic test was performed. The force was estimated for each cycle at 20%, 40%, 60% and 80% of the maximum load. The velocity ranged from approximately 0.4mm/min ± 0.1mm/min. The unloading phase was stopped at 200 N.

The compression tests were monitored in parallel with the AE 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 and allow the capture of signals. The detected signals were amplified with a 40 dB differential amplifier. The detection threshold was set at 33 dB to avoid the influence of any background noise. Figure 1 below shows the AE sensors positions. The 8 sensors and the way they are positioned allow to cover the whole surface and to localize damage in 3D with better precision.

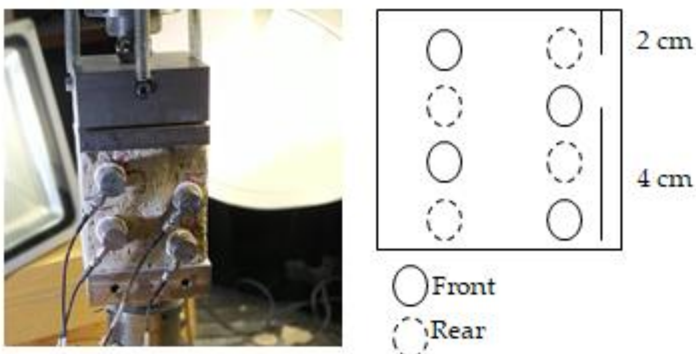


FIGURE 1. Experimental procedure and AE sensors positions

III. RESULTATS ET DISCUSSIONS

Kaiser Effect is satisfied when no AEs are captured before the previous maximum load (PML) is attained. If AEs were detected before PML, Kaiser Effect is not fulfilled and the process is characterized by the so-called Felicity ratio (FR). The latter is the stress at onset of AE to the previous maximum stress ratio as expressed in the equation below:

$$FR = \frac{stress\ at\ onset\ of\ AE(OOA)}{previous\ maximum\ stress(PMS)}$$

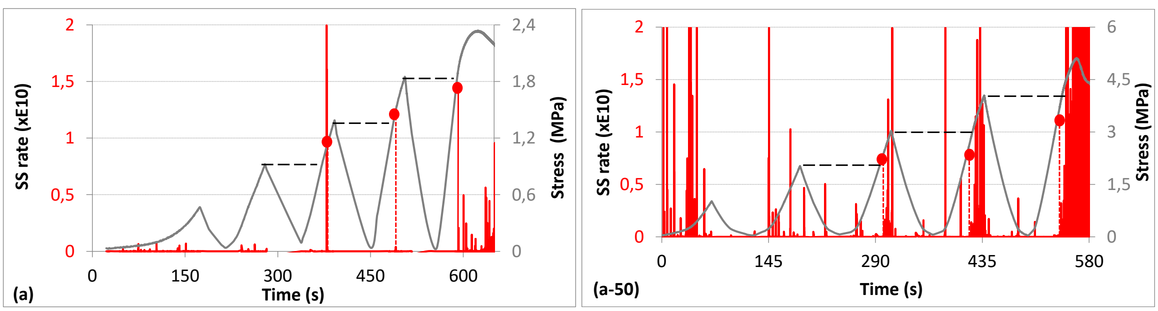
However, the term 'onset of AE' is controversial. Different approaches have been proposed to recognize properly the onset of AE activity, e.g., 'cumulative AE hits versus stress', 'hit rate versus stress'… The bilinear regression method and the method of two tangents have been proposed as well aiming for more accurate results. In addition, the slope deviation of 'cumulative number of signal strength (CNSS) versus time' is recognized as the 'onset of AE' has been adopted. Accordingly, based on the last approach, the AE activity, in this work, will be presented in terms of signal strength rate.

Figure 2 below shows the correlation of stress and AE activity characterized by signal strength (SS) rate of each mixture at RH=90% and RH=50%. The AEs recorded during at the beginning often mislead the interpretation of Kaiser Effect. In materials that exhibit similar AEs at the beginning, some authors tend to start by applying a sustained load not less than 30% to avoid such misinterpretation and probably starts from $PMS/P_{max} = 0.5$ (Meng et al., 2019) (PMS and P_{max} represent the previous maximum stress and the peak stress). In the following study, the assessment takes place starting from $PMS/P_{max} = 0.4$.

The stress-time curves in figure 2 are drawn based on the output of the AE technique. Starting from the mixture RS40/60 at RH=90%, undoubtedly, Kaiser Effect was attained at all cycles. The shape of the stress-time curve shows that no single AE activity was captured before the PML in any cycle. Regarding the other mixtures at RH=90%, it seems that Kaiser Effect was attained in the other RS mixtures with a potential of its nonfulfillment in the third cycle of the natural sand mixture (NS30/70).

Higher AE activities were revealed in the specimens exposed to drying. It can be stated, apparently, that Kaiser Effect was attained only at $PMS/P_{max} = 0.4$ in all mixtures with some doubts to the RS40/60 one. At later cycles, Kaiser Effect was basically not achieved in any mixture.

The transfer from achievement to no achievement of Kaiser Effect means that more damage has occurred. The nonfulfillment of Kaiser Effect in specimens at RH=50% though it was attained at RH=90% indicates that more damage has occurred for the specimens at dried conditions. Such damage is related to the shrinkage induced cracking (Fardoun, 2021). Interestingly, the mixture with higher clay content showed remarkable increase in AEs at dried conditions compared to its state at RH=90%.



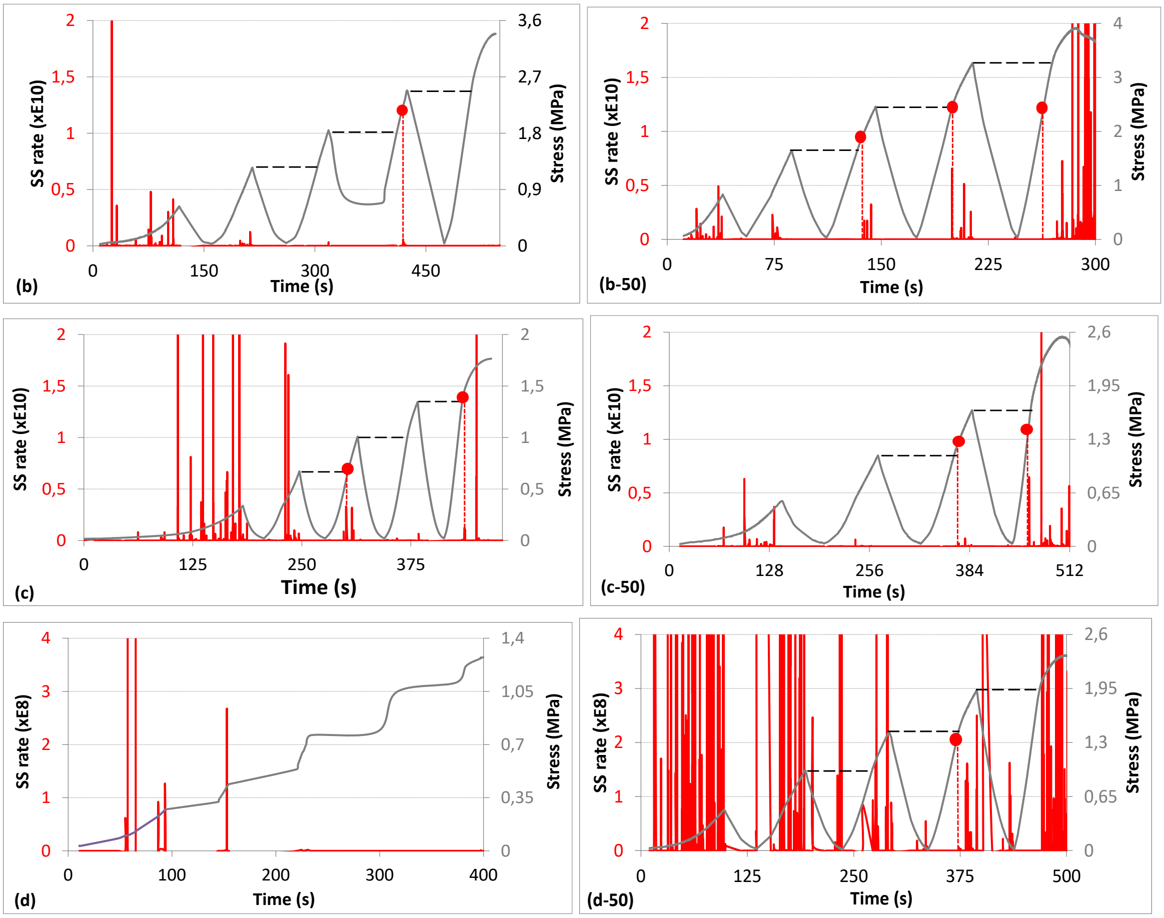


FIGURE 2. **Correlation between stress and and signal strength rate at RH=90% of (a) NS30/70, (b) RS20/80, (c) RS30/70 and (d) RS40/60 and at RH=50% of the same mixtures respectively**

IV. CONCLUSIONS

This work is an attempt to estimate the fulfillment of earth concrete mixtures at different curing conditions by displaying the stress and AE analysis. It can be stated that more damage was reported in dried specimens due to shrinkage induced cracking that was reflected by nonfulfillment of Kaiser Effect. Our next work will determine the felicity ratio of all specimens at RH=90% and RH=50%. More interestingly, it will assess the influence of clay at dried conditions as RS40/60 revealed remarkable increase in AE activity compared to its state at RH=90%.

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