Long term deformation monitoring of GRC façade panels under ambient conditions

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Abstract

Nowadays, the precast façade panels constructed with glass fibre reinforced concrete (GRC) are used as façade elements. These elements are exposed to different environmental conditions directly. Tracing the variations of the façade panels resulting from exposure to actual outdoor conditions is required to estimate their future performances.

A case study, which has been ongoing since 2010, is presented by the authors. In the study, two precast exterior wall panels were constructed in actual size with GRC. Then, these façade panels were installed onto a reinforced concrete frame. Lastly, in order to observe the performances of the façade panels under real environmental conditions, this system including the precast façade panels and the reinforced concrete frame were left outdoor in Ayazaga, Istanbul.

In order to determine the effect of the environmental conditions, the deformations of the panels are measured at regular intervals. Using the measurements, the average strains are calculated in different gage lengths and in different directions. An electronic measuring device, which was positioned onto the panels, is utilized to gage the ambient conditions (temperature and relative humidity) of the panels. The performances of the panels are represented with the plots drawn indicating the variations of the strains and the ambient conditions by time. Since 2010, although remarkable variations in the environmental conditions have been recorded, no damage is observed up to now.

Since 2010, although remarkable variations in the environmental conditions have been recorded in terms of temperature and humidity, no significant damage has been observed.

Keywords: Ambient condition, durability, GRC, Glassfibre reinforced concrete, GRC, precast, wall panel.

INTRODUCTION

Glass fibre reinforced concrete (GRC) is a composite material comprised of glass fibres and cement matrix. Glass fibres are added in order to improve the tensile properties of brittle cement matrix as well as the flexural strength and the toughness. Due to its superior properties such as fire and high corrosion resistance, GRC panels are commonly used in building industry. Easy mouldable and aesthetic features also make this material preferable for building façade cladding. When GRC panels are used in exterior applications such as façade cladding, they are subjected to ambient climate conditions in the long duration. Correia et al. (2006) reported that thermal effects are one of the most significant parameters leading extensive cracking on exterior GRC façade panels. They carried out in-situ experimental tests and proposed a kind of insulation as a rehabilitation solution in order to avoid the effect of thermal gradients on façade panels. Besides the thermal effects, especially in wet or humid conditions, one of another most important concern is the alkalinity of the cement mortar reducing fibre strength with time. However chemical properties of cement mortar and glass fibres have been significantly improved in recent years (Proctor et al., 1982). Alkaline resistant fibres have been developed and mortar additives have been utilized for reducing the corrosion on fibres due to alkalinity of mortar. Liang et al. (2002) compared different types of GRC specimens including fibres with and without alkaline resistant coating. Plain cement, glass fibre reinforced cement and coated glass fibre reinforced cement specimens were cured for 7, 28, 60, 90 and 150 days at C in a room having 100 % relative humidity. They found that GRC specimens with coated fibres have superior strength in compression and flexure at the end of the all of the curing durations. Gao et al. (2003) examined mechanical behaviour of the alkaline resistant fibres subjected to different surface treatments. Single fibre tests were carried out after each was conditioned in different solutions. They concluded that different sizing applications have different effects on the tensile characteristics of the fibres. Producers should guarantee the long-term use of these materials as façade cladding without any loss in strength or aesthetic. Therefore, in-situ observations and condition monitoring of GRC elements are very informative in order to define potential effects of ambient conditions on these elements. In the present paper, the results of a long term deformation monitoring study are presented. The study was conducted at Istanbul Technical University, Turkey. Two GRC façade panels have been left outside of the laboratory building since 2010 and in-plane deformations in different gage lengths and directions have been traced as well as variation of local ambient temperature and relative humidity values. Measured deformations are evaluated together with the ambient climatic values. It should be noted that the observations on the deformations and conditions of the panels during a period of September 2010-July 2011 were reported by Aydogmus et al. (2011).

CONSTRUCTION OF FAÇADE PANEL

The aim of this study is to monitor the long term performance of GRC panels under ambient conditions. For this purpose, two precast façade panels were constructed with glass fibre reinforced concrete (Figure 1). The wall panels have a thickness of 17 mm, a length of 2555 mm and a height of 1505 mm.

Figure 1. *The construction of the façade panel*

After the construction of the façade panels, they were transferred to Istanbul Technical University for installation onto a reinforced concrete frame and to be left in outdoor ambient conditions. For simulating actual in-situ condition and stress state of the façade panels, they were connected to an existing reinforced concrete frame with actual practical installation details. Figure 2 illustrates the appearance and geometrical dimensions of the reinforced concrete frame.

The façade panels, which were installed on the reinforced concrete frame, can be seen in Figure 3. In order to examine the effects of sunlight, the façade panels were installed on two sides of the reinforced concrete frame facing east (PN1) and west (PN2).

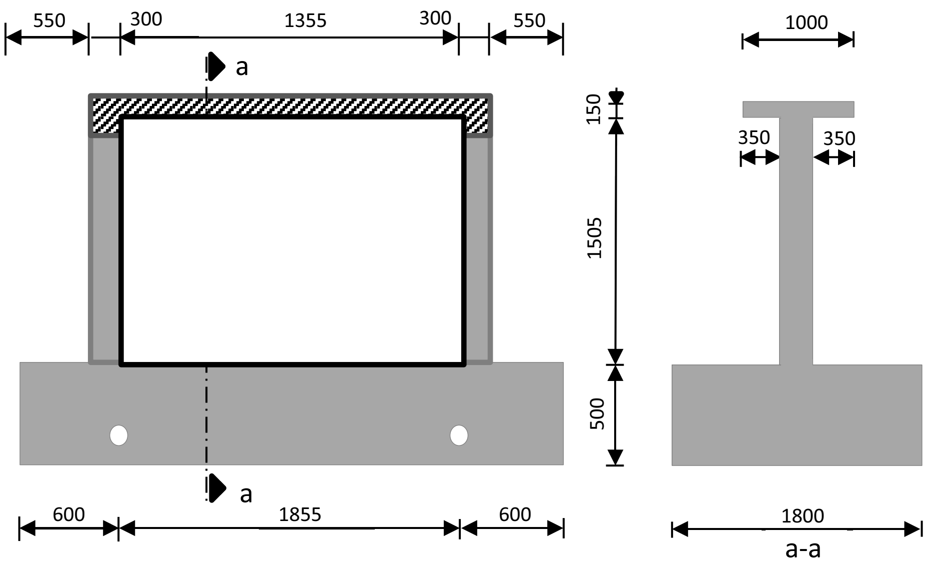

Figure 2. *The appearance of the reinforced concrete frame (all dimensions in mm).*

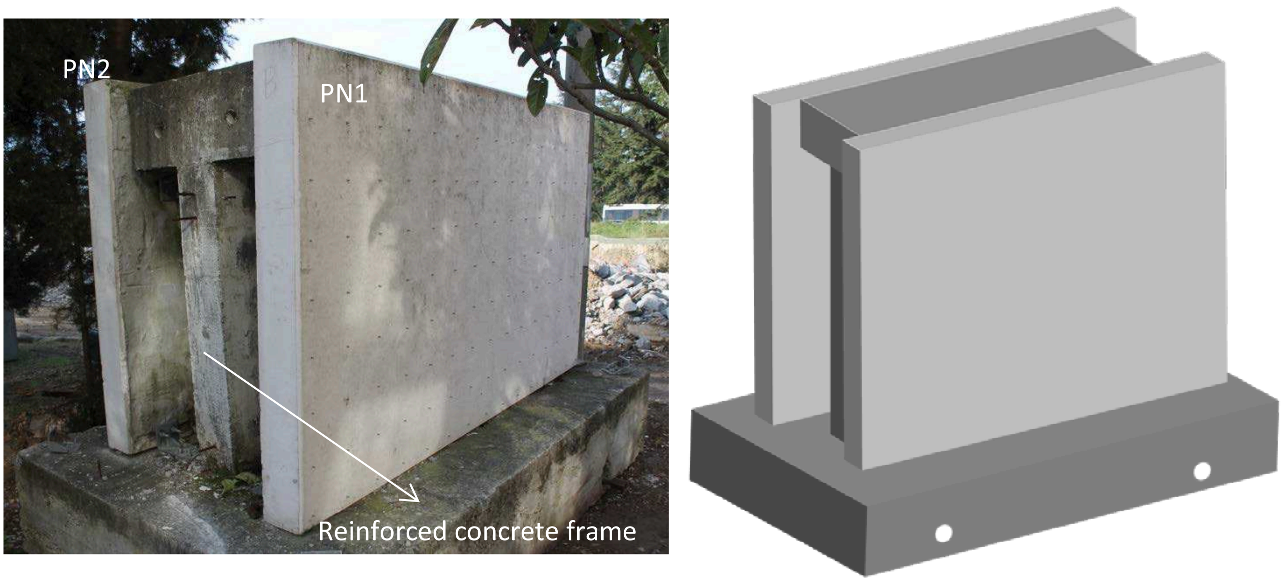

Figure 3. *The appearance of the façade panels installed into the frame*

MATERIAL PROPORTIES

The façade panels were constructed with a mixture of glass fibre, silica sand, Portland cement, mineral admixture, polymer, plasticiser and water. The mix-proportions of GRC are given in Table 1.

Table 1. *Mix-proportions of glass fibre reinforced concrete (mortar) (kg/)*

Silica sand	Portland cement	Mineral admixture	Polymer	Plasticiser	Fibre	Water
951	872	91	34	3	71	283

In order to determine the mechanical properties of GRC, compression and bending tests were carried out. The dimensions of the specimens used for the compression tests were 40x40x40 mm. The average compressive strengths of the specimens are given in Table 2 for PN1 and PN2 façade panels. It should be noted that the compression tests were performed at the age of 28 days and a total of 16 specimens were tested for determination of the compressive strengths of GRC.

Table 2. *Average compressive strength of glass fibre reinforced concrete (MPa)*

Specimen size (mm)	PN1	PN2
40x40x40	63	48

The dimensions of the specimens tested under bending loads were 275x50x11 mm. The four-point bending tests were carried out in accordance with TS EN 1170-5 (1999). A total of 16 specimens were tested. The average bending strengths at the age of 28 days are presented in Table 3 for PN1 and PN2 façade panels.

Table 3. *Average bending strength of glass fibre reinforced concrete (MPa)*

Age (day)	PN1	PN2
28	8.7	9.3

As seen in Tables 2 and 3, the mechanical characteristics determined experimentally are adequate for this type of non-structural façade panels. The details of the compression and bending tests can be found in Aydogmus et al. (2011).

MONITORING OF FAÇADE PANELS

The façade panels have been monitored since 2010. In order to monitor these panels, a measuring grid system was formed on exterior surface of each panel. As seen in Figure 4, the measuring grid system included a total of 135 points. The grid spacing was 175 mm. For measuring deformations, steel rods were left within the panels for forming the grid system (Figure 4). The deformation variation of the façade panels were determined by measuring the spacing of the grid points. The deformation measurements were made by a 0.02 mm-precision electronic device at regular time intervals beginning from the demoulding day, which is just one day after casting. The ambient conditions of temperature and relative humidity were simultaneously measured by a sensor and these measurements were recorded by a data logger. The sensor was positioned on the reinforced concrete frame to gage the ambient conditions which the panels were subjected to. The sensor was kept under a shelter to avoid damage due to environmental conditions.

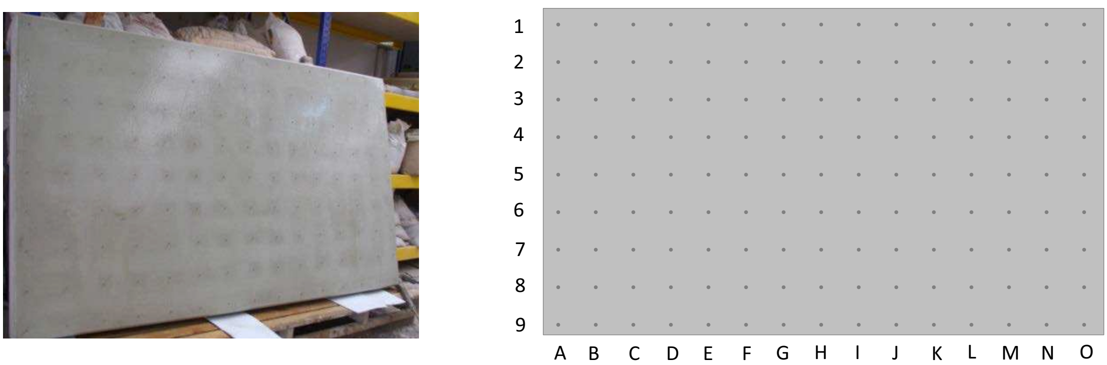

Figure 4. *The appearance of the measuring grid system*

The variations of the ambient conditions are presented in Figure 5 for temperature and in Figure 6 for relative humidity. As seen in these figures, while the temperature values corresponding to the measured strains varied between 0-33° C, the humidity values varied between 8-100%. However, it should be noted that the façade panels were subjected to a range of temperature between -7 and 37° C. Seasonal temperature fluctuations are apparently seen in Fig. 5. There is no complete dry season. While the relative humidity does not show a clear seasonal difference, maximum values are usually obtained in winter and minimum values are obtained in summer. In order to clarify the effect of the ambient conditions on the deformations of the panels, the average strains are calculated for different paths, namely, in different gage lengths (175, 350, 700 and 1400 mm) and in different directions (horizontal, vertical and diagonal directions) as seen in Figure 7. For these paths, the strains are plotted in Figure 8 for PN1 and in Figure 9 for PN2 façade panel.

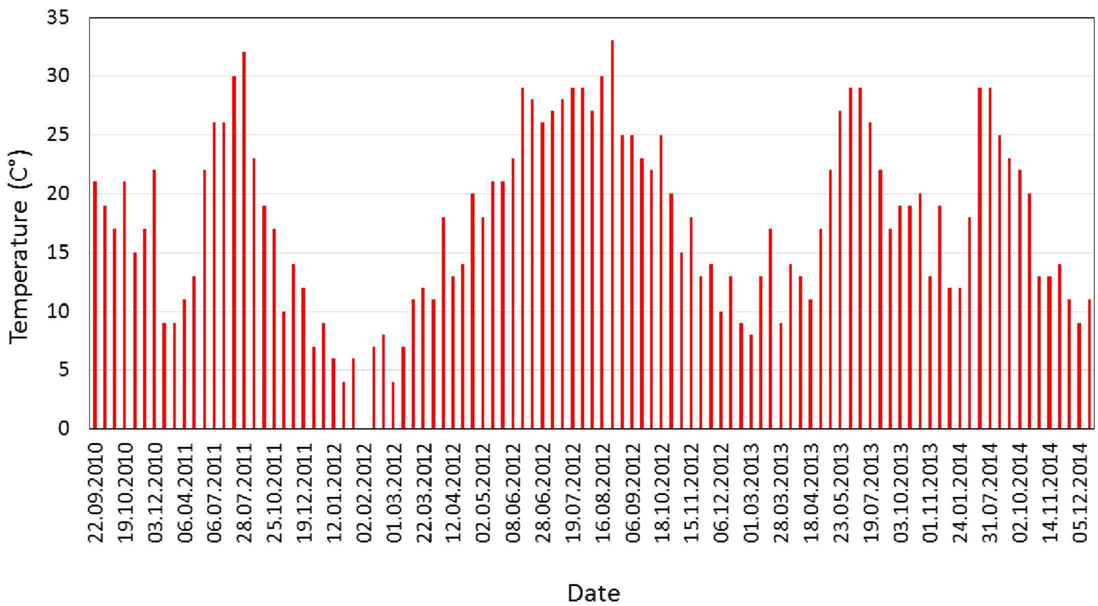

Figure 5. *The variation of temperature by time*

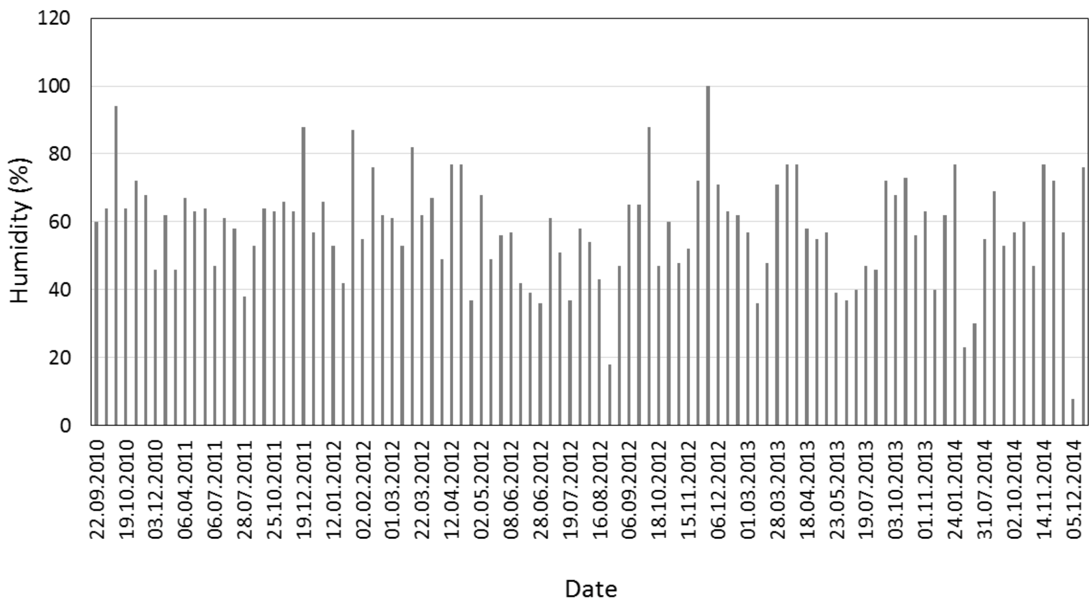

Figure 6. *The variation of relative humidity by time*

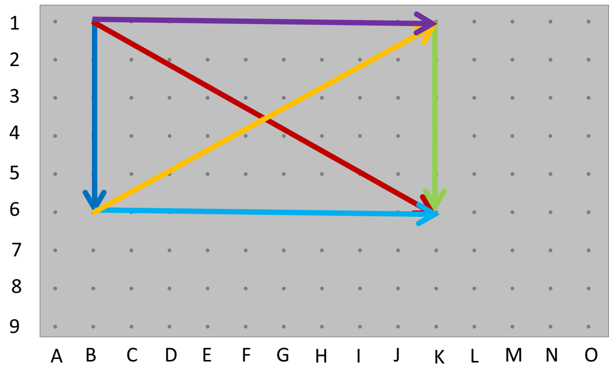

Figure 7. *The paths adopted for the calculation of the strain*

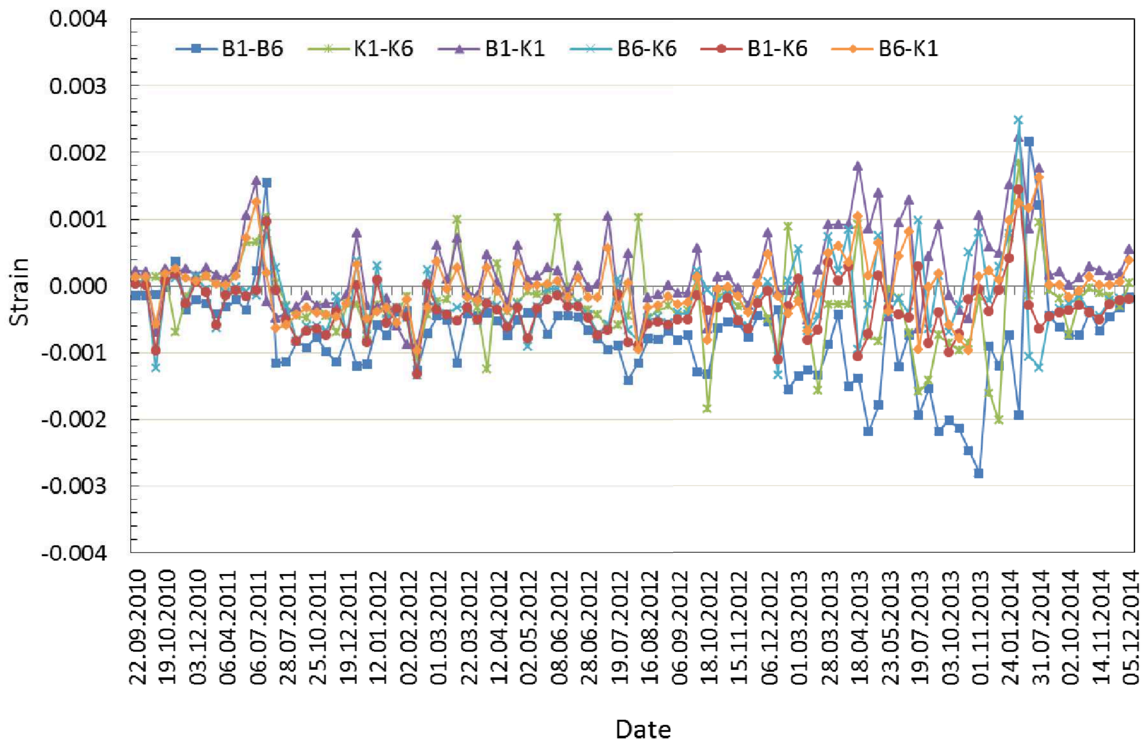

Figure 8. *The evolution of strain by time for PN1 façade panel*

As seen from Figures 8 and 9, the strains determined for each path show generally similar tendencies such as expansion or contraction at the same time interval. This may be due to the uniform distribution of glass fibre and the other mixture components of glass fibre reinforced concrete as well as a good workmanship. Especially for PN1 panel, the strain amplitude has remarkably increased at the period of April 2013-August 2014. After August 2014, the strain amplitude is decreasing. The maximum absolute values of the strains for PN1 panel are 0.0028 for B1-B6, 0.0020 for K1-K6, 0.0022 for B1-K1, 0.0025 for B6-K6, 0.0014 for B1-K6, 0.0016 for B6-K1. The maximum absolute values of the strains for PN2 panel are 0.0024 for B1-B6, 0.0025 for K1-K6, 0.0022 for B1-K1, 0.0020 for B6-K6, 0.0017 for B1-K6, 0.0017 for B6-K1.

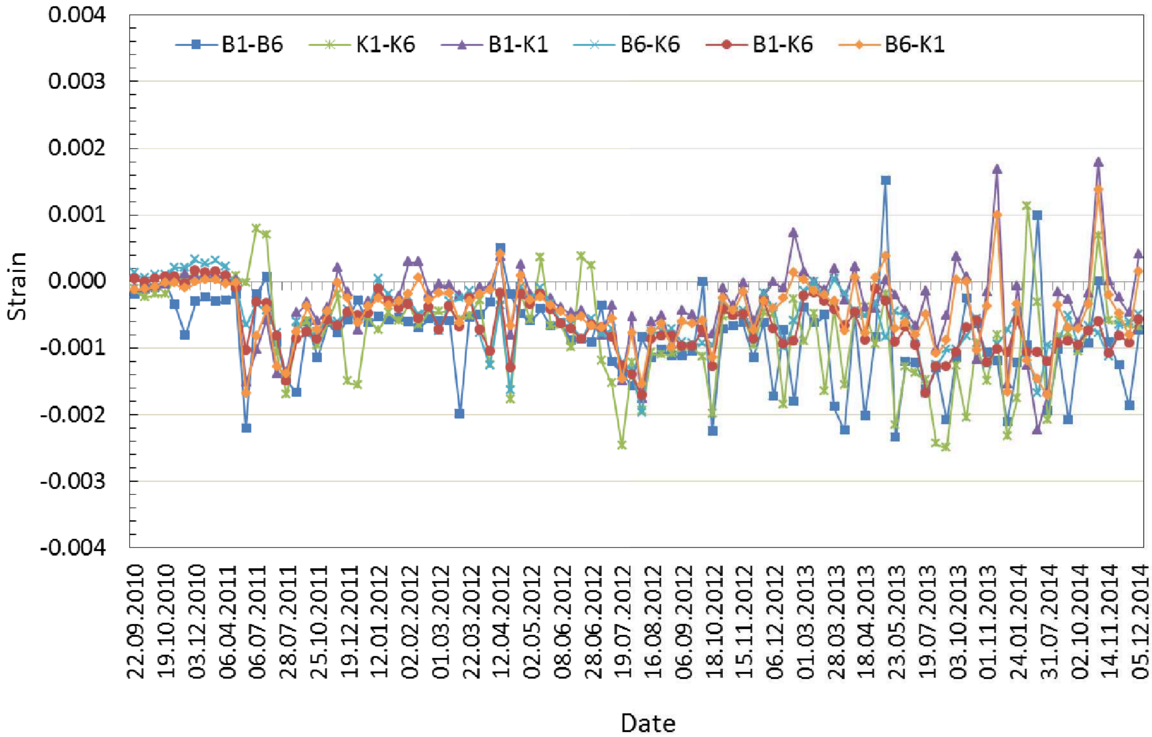

Figure 9. *The evolution of strain by time for PN2 façade panel*

As a result, although the remarkable variations in the ambient conditions have been recorded since 2010, no visible damage due to ambient climatic conditions has been observed up to now.

CONCLUSIONS

The performances of GRC façade panels under ambient conditions have been observed since 2010. The observations made during the period presented in this paper. Although the façade panels were subjected to a range of the temperature between -7 and 37° C, it is detected that there is no visible damage at the façade panels up to now.

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