# 8 Deformations of precast Glassfibre Reinforced Concrete Exterior Wall Panels Under Ambient Conditions – a pilot study

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**Abstract**

The use of precast glass fiber reinforced concrete exterior wall panels are increasing day by day due to their various advantages in construction. Since these non-structural building components are exposed to different environmental conditions, knowledge on the deformations of these members under different environmental conditions are extremely important not only for strength and durability, but also for aesthetical concerns. In this pilot study, two actual size exterior wall panels are connected onto an actual reinforced concrete frame by using actual connection details and these members are left in outdoor ambient conditions in Maslak, Istanbul. The deformations of these members are measured with regular time intervals beginning from the demoulding day, which is just one day after casting. The regular deformation measurements are carried out through a 0.02 mm-precision electronic device within the gage lengths of 175 mm. The measurements are then utilized for determining the average deformations in different gage lengths, such as 175, 350, 700, 1400 mm and in different directions, such as horizontal, vertical and diagonal directions. The ambient conditions, such as temprature and relative humidity are also measured and recorded simultaneously by electronic measuring devices. In parallel to the deformation measurements, various material tests were also carried out to fully understand the mechanical characteristics of the glass fiber reinforced concrete used in the construction of the precast wall panel. At the end of this pilot study, as well as obtaining extensive data on the material mechanical characteristics, the distribution of deformations throughout the wall panel in different directions and different gage lengths are obtained systematically. Finally, the variation of these deformations are evaluated considering the variation of ambient conditions, such as tempretaure and relative humidity.

## Introduction

In this study, the performance the precast glass fiber reinforced concrete exterior wall panels under ambient conditions are examined. The main purpose of the study is the observation of the performance within longer period through deformation measurements in different directions on the specimens, which are subjected to natural variations of temperature and humidity in Istanbul. Therefore, the measurements are going on and planned to continue in the long run as well.

After production, the precast glass fiber reinforced concrete exterior wall panels are transferred to Istanbul Technical University. Then the wall panels are connected to an existing reinforced concrete frame following the installation methodology used in practice. The precast glass fiber reinforced concrete exterior wall panels connected to the reinforced concrete frame can be seen in Figure 1. For examining the different effects of sunlight, the exterior wall panels are adjusted to face to east and west respectively. The dimensions of the wall panels and the frame that the panels are connected are shown in Figures 2a and 2b, respectively. It should be noted that the measuring grids on the panel can also be seen in Figure 2a. Appearances from an actual installation application are also presented in Figure 3.


Figure 1. Appearance of the precast wall panels

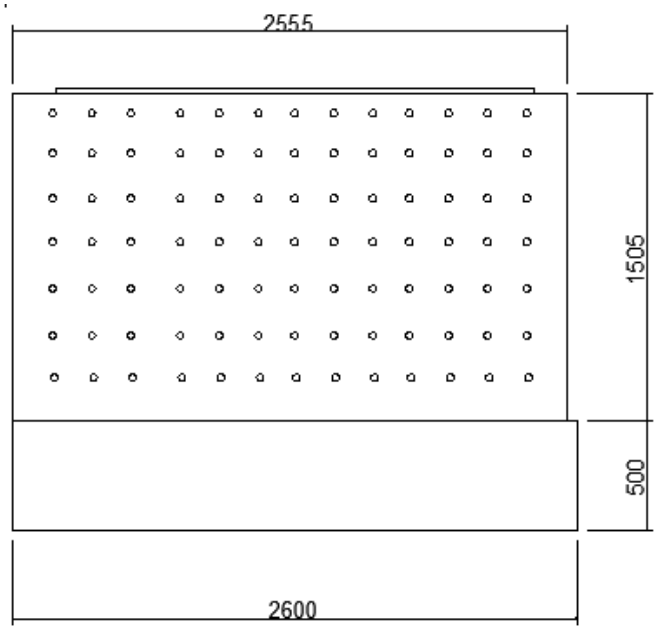



Figure 2a. Dimensions of the wall panel and measuring points (dimensions in mm)

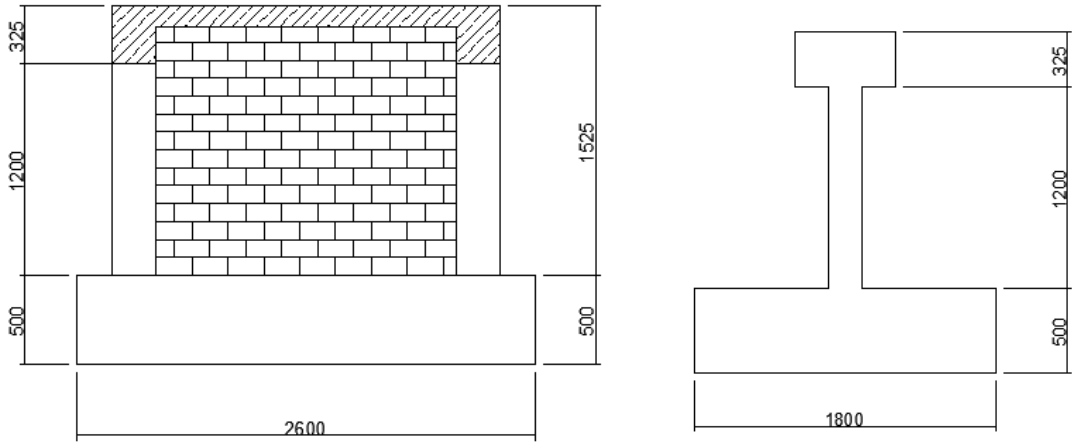



Figure 2b. Dimensions of the frame (dimensions in mm)

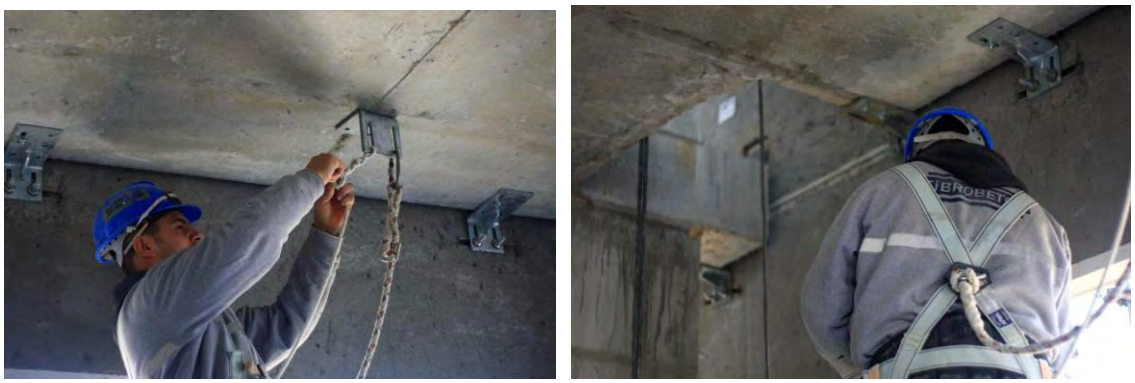


Figure 3. An appearance from actual installation of wall panels

**Material Properties and Material Tests**

The mix-proportion of the glass fiber reinforced concrete (mortar) for cubic meter used in the production of the specimens is as follows: 615 kg silica sand, 720 kg Portland cement, 205 kg water and 70 kg mineral admixture. The glass fibers added in the mixture is 4% of cement by weight. For characterization of the mechanical properties of the material used for the production of the wall panels, compression and bending tests are carried out. The appearances from the compression and bending tests can be seen in Figures 4 and 5, respectively. The compression tests were carried out at the age of 28 days, while bending tests were carried out at the ages of 7 and 28 days. A damaged specimen after being subjected to bending test is also shown in Figure 5. As seen in this figure, the remarkable ductility of glass fiber reinforced concrete is demonstrated through very high plastic deformations.

The dimensions of the specimens used for compression tests were 40x40x160 mm and 40x40x40 mm, while the dimensions of the specimens tested under bending were 275x50x11 mm. It should be noted that for each panel, eight specimens are tested under bending. The configuration of specimens taken from a panel can be seen in Figure 6. For assessing the potential effects in terms of directivity, as seen while four specimens are taken from longitudinal direction, the remaining four specimens are taken from transverse direction. Furthermore, to assess any kind of potential influence of casting direction, half of the specimens were tested upside down. The results of material tests for compression and bending are outlined in Tables 1 and 2, respectively. In Tables 1 and 2, PN1 and PN2 is used for panel 1 and panel 2, respectively.

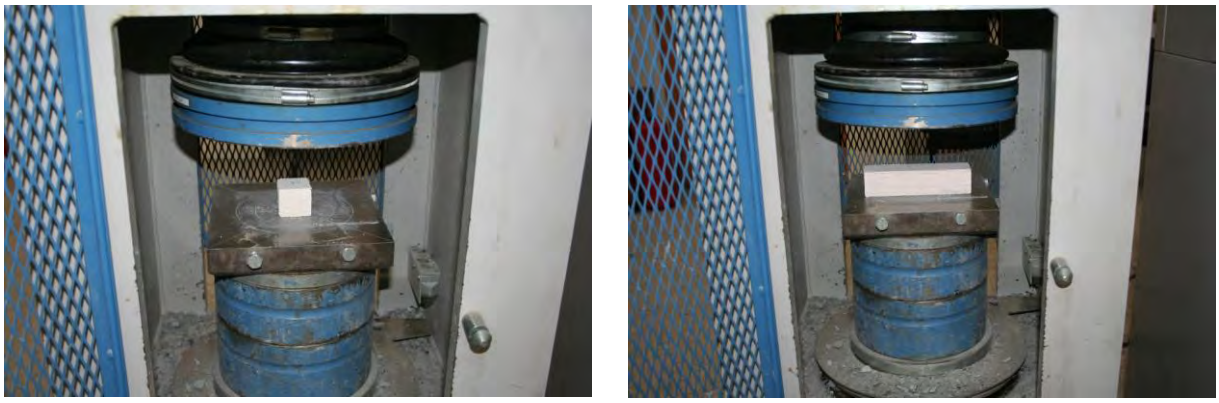


Figure 4. Compression tests and specimens used for compression tests

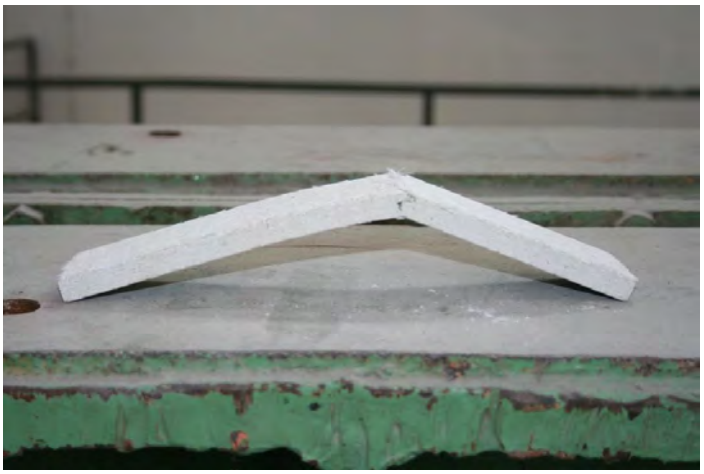


Figure 5. Bending tests and appearance of a specimen after test

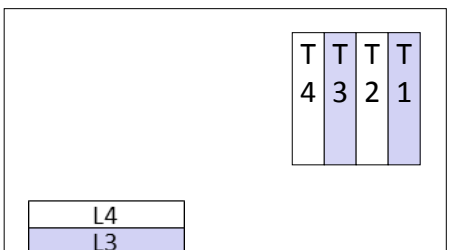


Figure 6. Specimens for bending tests

As seen in Tables 1 and 2, while the scatter is much less in case of compression tests, there is a quite high scattering of test results in case of bending tests. Nevertheless, it should be noted that these members are not main structural members and the obtained mechanical characteristics are satisfactory for this type of nonstructural exterior walls.

Table 1. Results of compression tests at 28 days age

| PN1 | | | | | |
|---|---|---|---|---|---|
| 40 x 40 x 160 mm. | Load (kN) | $\sigma_{C\ (MPa)}$ | | Load (kN) | $\sigma_{C\ (MPa)}$ |
| | 493.2 | 77 | 40 x 40 x 40 mm. | 97.3 | 61 |
| | 501.5 | 78 | | 91 | 57 |
| | 497.5 | 78 | | 97.2 | 61 |
| | 509.9 | 80 | | 101.2 | 63 |
| | 491.9 | 77 | | 104 | 65 |
| | 485.3 | 76 | | 100 | 63 |
| | 493.5 | 77 | | 104.6 | 65 |
| | 485.8 | 76 | | 106.8 | 67 |
| | Mean | 77 | | Mean | 63 |
| | St.Deviation | 1.3 | | St.Deviation | 3.2 |

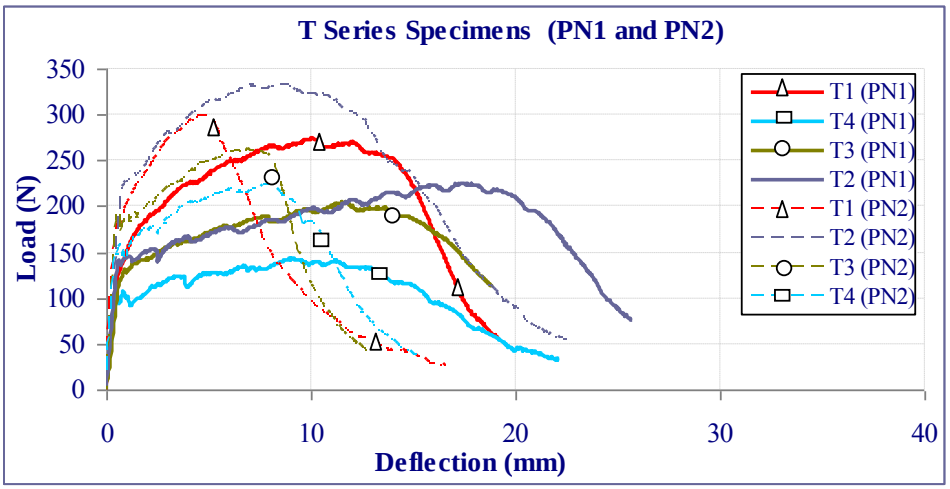
| PN2 | | | | | |
|---|---|---|---|---|---|
| 40 x 40 x 160 mm. | Load (kN) | $\sigma_{C\ (MPa)}$ | | Load (kN) | $\sigma_{C\ (MPa)}$ |
| | 411.8 | 64 | 40 x 40 x 40 mm. | 82.5 | 52 |
| | 407.1 | 64 | | 75 | 47 |
| | 431.4 | 67 | | 73.6 | 46 |
| | 401.1 | 63 | | 78.4 | 49 |
| | 396.6 | 62 | | 79.1 | 49 |
| | 441 | 69 | | 71 | 44 |
| | 411.5 | 64 | | 75.2 | 47 |
| | 418.6 | 65 | | 81.7 | 51 |
| | Mean | 65 | | Mean | 48 |
| | St.Deviation | 2.3 | | St.Deviation | 2.5 |

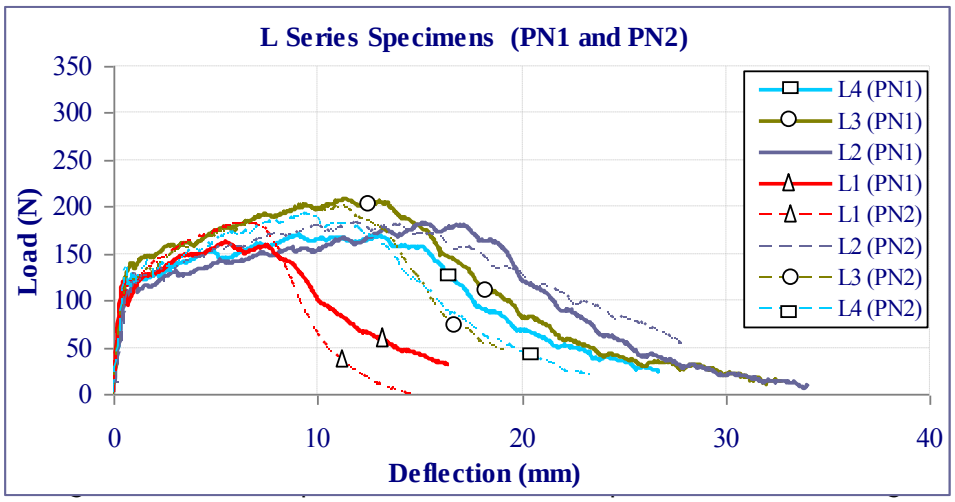
Table 2. Results of bending tests at 7 and 28 days of age

| | 7 Days | | 28 Days | |
|---|---|---|---|---|
| | PN1 | | PN2 | |
| | $\sigma_{MOR\ (MPa)}$ | $\varepsilon_{MOR}$ | $\sigma_{MOR\ (MPa)}$ | $\varepsilon_{MOR}$ |
| T4 | 4.22 | 0.00658 | 9.25 | 0.00662 |
| T2 | 5.99 | 0.00518 | 11.56 | 0.00779 |
| L4 | 4.72 | 0.00783 | 7.94 | 0.00798 |
| L2 | 6.41 | 0.00822 | 7.57 | 0.00984 |
| *T3 | 5.41 | 0.01014 | 9.91 | 0.00599 |
| *T1 | 8.98 | 0.00506 | 10.38 | 0.00446 |
| *L3 | 4.44 | 0.00695 | 10.18 | 0.00703 |
| *L1 | 5.13 | 0.00496 | 7.52 | 0.00531 |
| **Mean** | 5.66 | 0.00686 | 9.29 | 0.00688 |
| **St. Deviation** | 1.54 | 0.00182 | 1.49 | 0.00169 |

| | 7 Days | | 28 Days | |
|---|---|---|---|---|
| | PN2 | | PN1 | |
| | $\sigma_{MOR\ (MPa)}$ | $\varepsilon_{MOR}$ | $\sigma_{MOR\ (MPa)}$ | $\varepsilon_{MOR}$ |
| T4 | 8.44 | 0.00442 | 5.93 | 0.00756 |
| T2 | 9.61 | 0.00371 | 9.32 | 0.01443 |
| L4 | 6.01 | 0.00702 | 8.52 | 0.00683 |
| L2 | 4.97 | 0.00483 | 9.24 | 0.01136 |
| *T3 | 8.83 | 0.00635 | 8.26 | 0.00969 |
| *T1 | 13.13 | 0.00588 | 11.11 | 0.00833 |
| *L3 | 6.27 | 0.00652 | 10.43 | 0.00852 |
| *L1 | 8.15 | 0.00550 | 6.73 | 0.00456 |
| **Mean** | 8.18 | 0.00553 | 8.69 | 0.00891 |
| **St. Deviation** | 2.56 | 0.00114 | 1.74 | 0.00299 |

While the compressive strengths and flexural strengths of the specimens are outlined in Tables 1 and 2, their flexural deformations characteristics through the load-displacement relationships obtained during bending tests. The load-mid span deflection curves of the specimens tested under bending are presented in Figure 7. As seen in this figure, while scatter is high, the flexural behavior of specimens is very ductile, as also demonstrated in Figure 5.




**Development of deformations by time**

For long term monitoring of deformations of precast glass fiber reinforced concrete exterior wall panels, the deformations of two specimens are measured in certain time intervals beginning from

the time that the walls were taken out from their formworks. For measuring deformations, steel rods were left within the walls at predefined coordinates precisely. Then the distances between all these steel rods were measure with high precision caliber gages of 0.01 mm accuracy.

While the deformations were measured and recorded periodically, the tempreture and humidity of the environment were also measured at the times of deformation measurements. The variation of temperature in C° and relative humidity (%) during the period of deformation measurements are presented in Figures 8 and 9, respectively. It should be noted that specimens PN1 and PN2 were produced on September 21, 2010 and September 24, 2010, respectively.

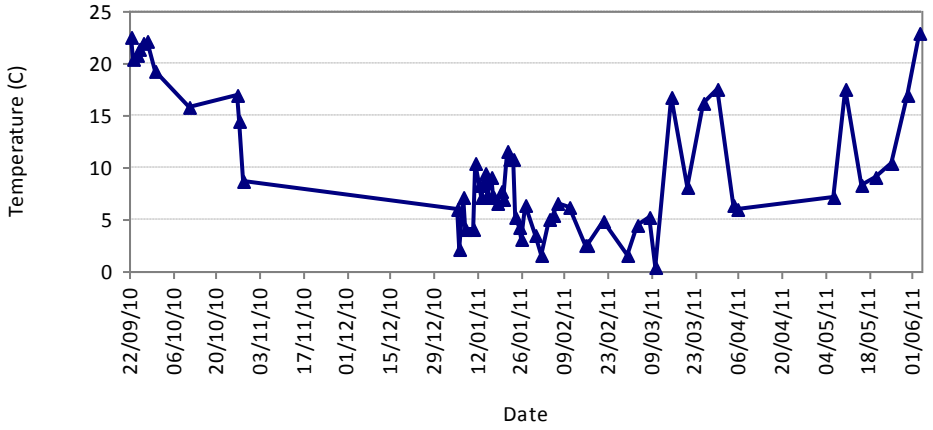



Figure 8. Variation of temperature during deformation measurement period

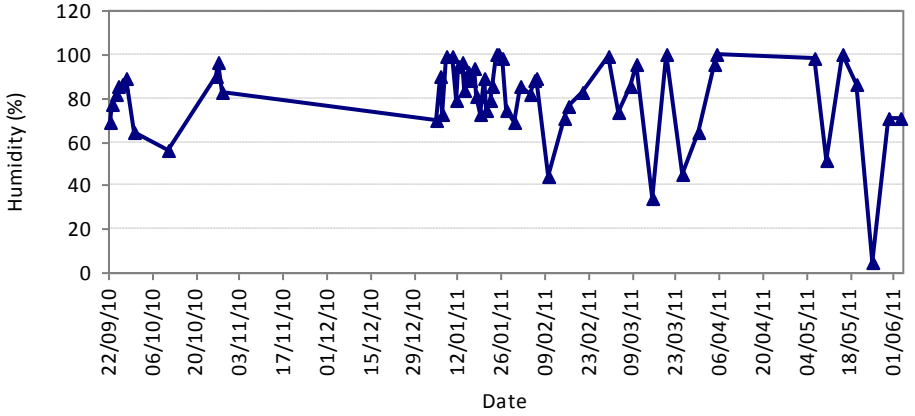



Figure 9. Variation of temperature during deformation measurement period

As seen in Figures 8 and 9, there are remarkable variations in temperature and humidity during the period of deformation measurements. It should be noted that the deformations are still going on and it is planned to continue the measurements further to obtain the performance in long run.

The variations of deformations in different directions and in different gage lengths are summarized compactly in Figures 10-14 for panel 1 and panel 2(PN 1, PN2) in a comparative manner. While the

deformation variations are presented in Figures 10 and 12, the gage lengths and directions are shown in Figures 11 and 13, respectively.

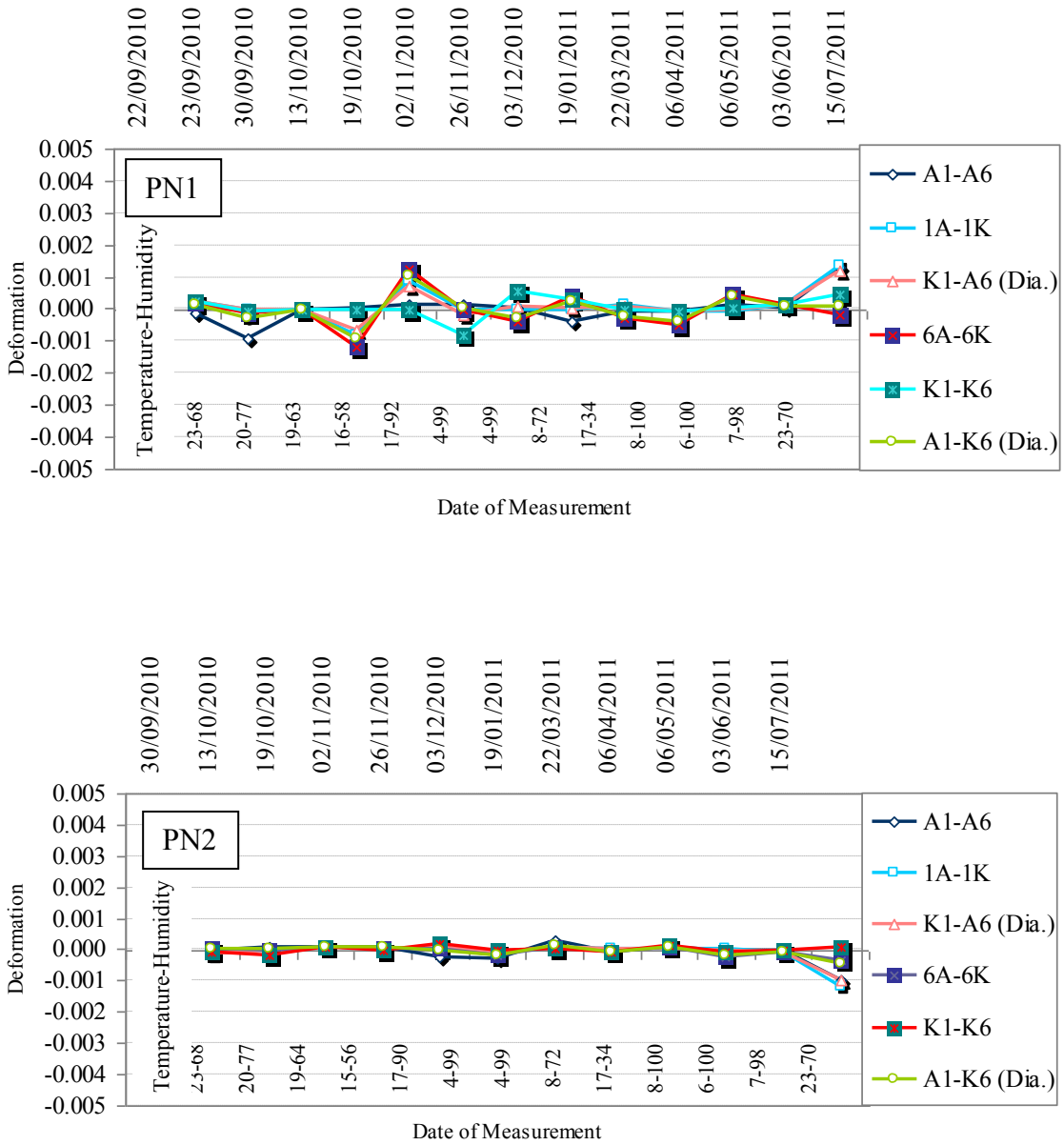



Figure 10. Average deformations in PN1 and PN2

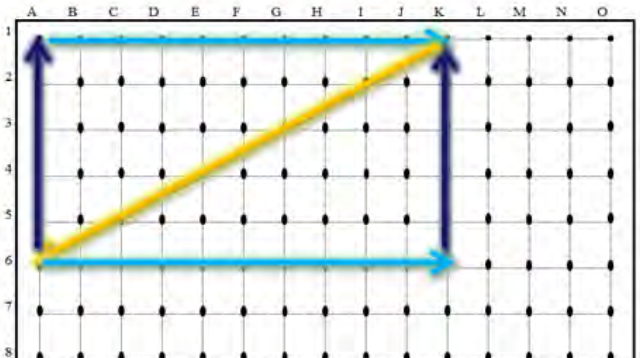
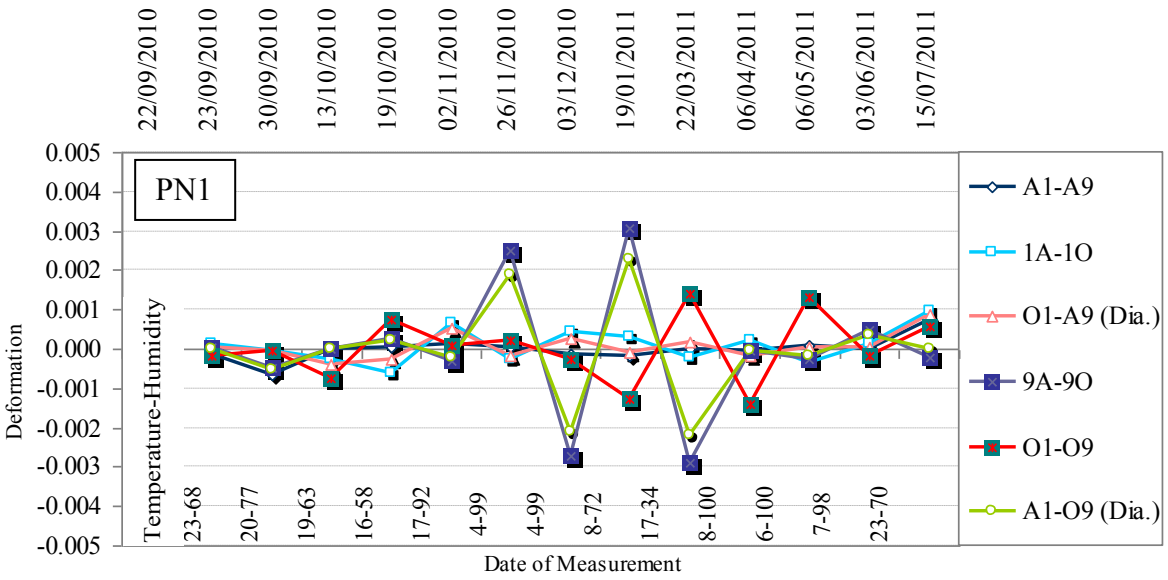


Figure 11. Gage lengths and directions for deformation measurements shown in Figure 10



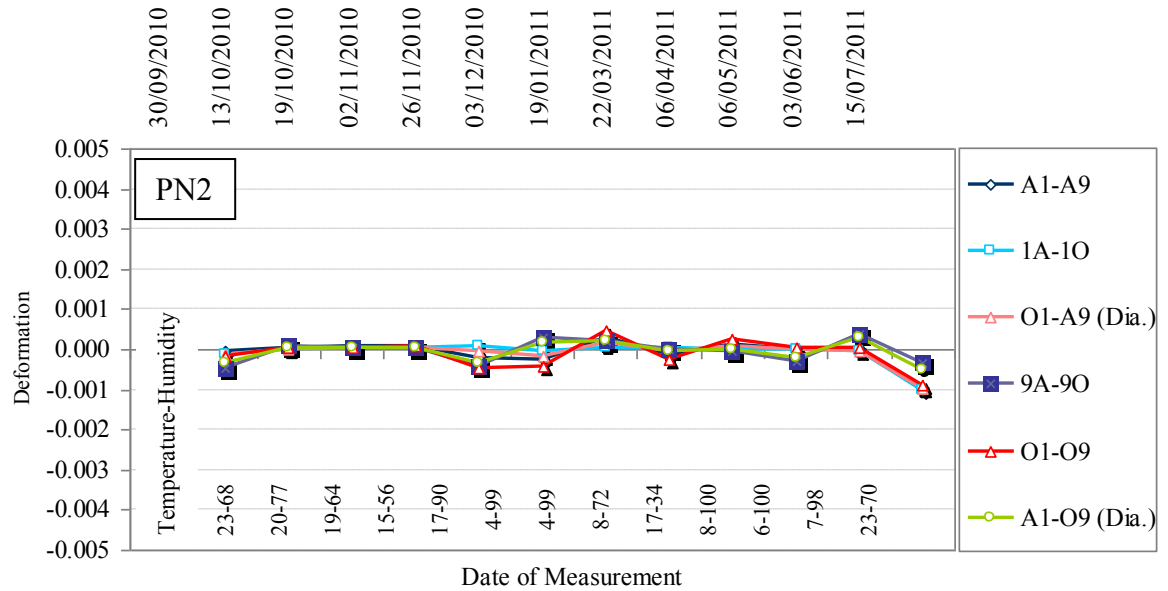




Figure 12. Average deformations in PN1 and PN2

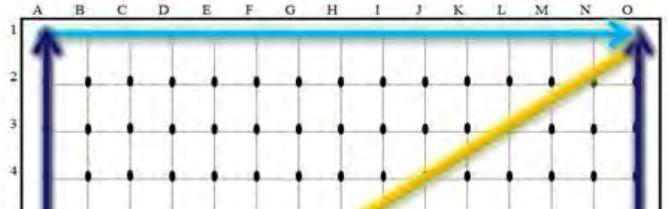


Figure 13. Gage lengths and directions for deformation measurements shown in Figure 12

It is important to note that the deformations given in Figures 10 and 12 are calculated by dividing the changes of distances to the original distances between the points indicated on the the legends of the graphics. Detailed explanation of the points shown on the legends can be seen in Figures 11 and 12. It is also worth to note that the measured deformations did not cause any cracking on the panel walls.

## Conclusions

Several basic material tests and long term deformation measurements are executed on the precast glass fiber reinforced concrete exterior wall panels. The basic material test results demonstrated that the panels can exhibit a remarkably ductile behavior based on the inherent ductile characteristics of their constituents, which are steel and glass fiber reinforced concrete. During long term deformation measurement tests, the wall panels are subjected to remarkable variations of temperature and humidity for about one year. While the measurements are going on periodically in the ambient conditions of Istanbul, up to now no damage is observed on the wall panels. While the deformations in different gage lengths and directions vary by time, due to mainly the thermal effects, these variations did not cause any undesired effect for now. The measurements are planned to continue for observing the performance even for longer periods. It is clear that to generalize the conclusions, further work is necessary in terms of other environmental conditions and different restraints and sizes of the panel walls.

## Acknowledgements

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