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Measurement of panel deformations of a polymer reinforced soil bridge abutment

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ABSTRACT: A polymer reinforced soil ("PRS"), wall system has been used for bridge abutment and retaining wall construction for some of the junctions on the Black Sea Coastal Road Project located in the north east of Turkey. Elements of the "PRS" wall system and the monitoring setup were briefly explained. Reinforcement elements used in the wall system are polymer strips consisted of high strength synthetic fibres encased in polymeric sheath. The panel deformations during different stages of the construction of A2 abutment on the Arakli Junction were measured with a servo controlled fully automatic electronic total station system using automatic polar recognition. Deformation measurements were taken after the construction of the bankseat and after the installation of the beams, results were compared with similar work. Applying initial batter for the panels during installation proved to be satisfactory. "PRS" bridge abutments built on areas acquired by filling the sea where pile foundations are required for classical reinforced concrete structures, provided not only savings but ease of construction as well.

1 INTRODUCTION

A dual carriageway project has been constructed on the Black Sea coast of Turkey. The retaining walls of the approach ramps and the bridge abutments of the nine junctions forming the 28 km section between the towns of Arakli and Iyidere on the north east coast were designed using a polymer reinforced soil ("PRS"), wall system. Due to the mountainous nature of the region, the dual carriageway has to be constructed on the narrow coastal band where small villages are scattered. In order to minimize land expropriation some sections of the carriageway and especially one of the approach ramps of the overpasses were constructed on areas reclaimed from sea. The overpasses are generally two span bridges. Although three out of nine middle piers were constructed on pile foundations, the abutments were constructed either on the areas reclaimed from sea or on natural ground. The flexible nature of the "PRS" wall system permitted the construction of the abutments without pile foundations thus providing savings on the project

As "PRS" bridge abutments shall be constructed very close to the coast, the designer of the "PRS" structures decided to monitor one the abutments. For this purpose the A2 bridge abutment of the Arakli Junction was selected.

In this paper, the basics of monitoring were explained and the results obtained were compared with similar tests together with the observations of the performance of "PRS" structures constructed on junctions which are now open to traffic.

2 THE "PRS" WALL SYSTEM

2.1 *Elements of the "PRS" wall system*

The main elements forming the "PRS" wall system are precast concrete facing panels, reinforcement strips, attachment elements and fill material (Fig. 1). Polypropylene dowels, joint filler, EPDM bearing pads, rear fixing bar are the accessories used during the construction.

Precast concrete panels are 16 cm thick and has a surface area of 3.20 m^2. Attachment loops are galvanized steel cast into the panels, protruding part is coated with polyethylene. Toggles are manufactured from steel, coated with polyethylene and connects the strips to the panels. Provided that the toggle bar is equal to or greater than 25 mm in diameter, there is no loss in strength of the polymeric strip as it will sustain the full breaking load because of its flexible nature. Fill material, preferably granular or with little cohesion should have a gradation curve falling between the limits given in Table 1.

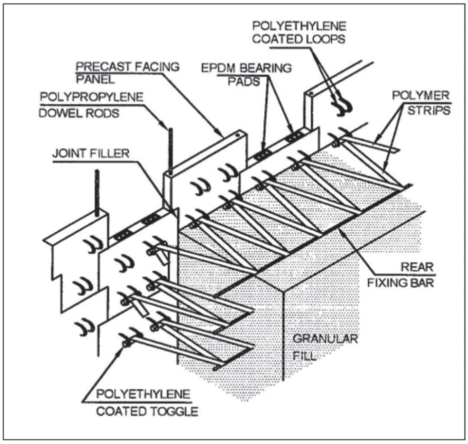

Figure 1. Elements of the "PRS" wall system, Price & Özçelik, (1994).

Table 1. Sieve analysis limits for the fill material.

ASTM Sieve Size	% Passing
8"	80-100
4"	60-100
3/4"	15-100
No. 4	10-100
No. 30	5-70
No. 200	0-17

Polypropylene dowel rods hold the panels in place during construction until panels are secured with wooden clamps. An initial batter is applied to the panels allowing for the movement due to compaction during construction. Joint filler is used to caulk the joints. Bearing pads prevent the concrete to concrete contact at horizontal joints when the panels are installed and absorb any minor settlements that may occur during compaction. Rear fixing bar is a constructional aid to hold the polymer strips firmly on the ground. The design takes into account that on the basis of friction only, the length of the strip from the point of maximum tension to the rear end is sufficient to create a stable mass. Furthermore, the load at the end of the strip is zero and thus no load is transferred around the strip at the rear bar.

2.2 *Properties of the reinforcement strip*

The reinforcement strips used in the "PRS" structures consists of discrete bundles of closely packed high strength synthetic fibres, lying parallel to each other, encased in a tough and durable polymeric sheath, manufactured in the UK and known as "Paraweb™". The 100 kN type is used for the abutments which has a width of 90 mm. 30 kN and 50 kN types are used in retaining walls. The polymer strips are delivered to site in 100 m coils and are laid continuously in a zig zag form.

The polymeric strips in the reinforced soil bridge abutments are designed to less than 33% of their breaking load. The load in the strips varies along the length of the strip from a maximum to zero; but this variation of the tension does not develop along the whole length under working load conditions. Under working loads, it extends from a maximum at the line of locus of maximum tension to a point at about half the distance between the point of maximum tension and the "free" end where it becomes zero (Schlosser et al. 1993). The post construction strains are less than 0.5% which is the requirement for bridge abutments for the serviceability limit state. Therefore there is no creep of any significance after construction.

In the "PRS" bridge abutments where there is an acute angled corner, the free end of the polymer strips on the abutment panels can be connected directly to the wing wall panels hence reducing anchorage length for friction (Fig. 2).

Figure 2. Polymer strip laying in A2 abutment on K2A Junction, Özçelik (2004).

3 THE MONITORING SETUP

3.1 *Location and equipment*

K2A Arakli junction is a two span overpass permitting an access to Arakli village from the carriageway through a slip road. The "A2" bridge abutment of this overpass was constructed directly on the area reclaimed from sea (Fig. 3).

The total height of the abutment on average is 9.0 m of which 6.80 m corresponds to the panels. The axis of the bankseat beam has a skew angle of 43°.

The monitoring was performed with a Leica TCA 1800 servo controlled fully automatic electronic total station system using automatic polar recognition. The total station was based at the roof of one of the nearby houses.

Thirty five points were selected for monitoring, due to lack of visibility it was difficult to monitor all of the points. Some of the points were used for reference.

Figure 3. View of A2 abutment on K2A Junction.

A total of twenty one points were used to form five columns for the monitoring of the "PRS" wall abutment "A2". It was impossible to target the "A1" abutment from the roof of the house where the total station was based. Unfortunately the "A1" abutment faces the sea and no building was available from where it can be targeted for monitoring.

3.2 *Loading*

After the panel installation was completed a base (zero) reading was taken in June 1999. Following the first loading, i.e. the construction of the bankseat (50.38 kN/m^2), the second reading was taken in October 1999. Third reading took place in December 1999 after the installation of the precast beams (70.00 kN/m^2). The intention was to make a final reading after the overpass was open to traffic, however due to an ongoing court case for the expropriation of a nearby building, the overpass is not in service.

4 RESULTS

At the end of the monitoring, deformations of the points in x, y, z directions were obtained. Vertical alignment of the abutment and the settlement of the base panels were evaluated from these data. The results are presented in Fig. 4.

Except three points, in general there is an outward deformation of 15-20 mm on the vertical alignment of the abutment. The maximum deformation reaches 25 mm at points no. 12 and no. 28. The deformation of point no. 27 is slightly less than 25 mm.

The deformations of the four points (no. 19, 20, 24, 28) were used to evaluate the settlement of the base panels. Maximum settlement of 5.5 mm is measured at the end of the installation of the beams.

The amount of deformation after the installation of the beams is found to be constant and varies between 7-11 mm, in all of the five columns that were monitored.

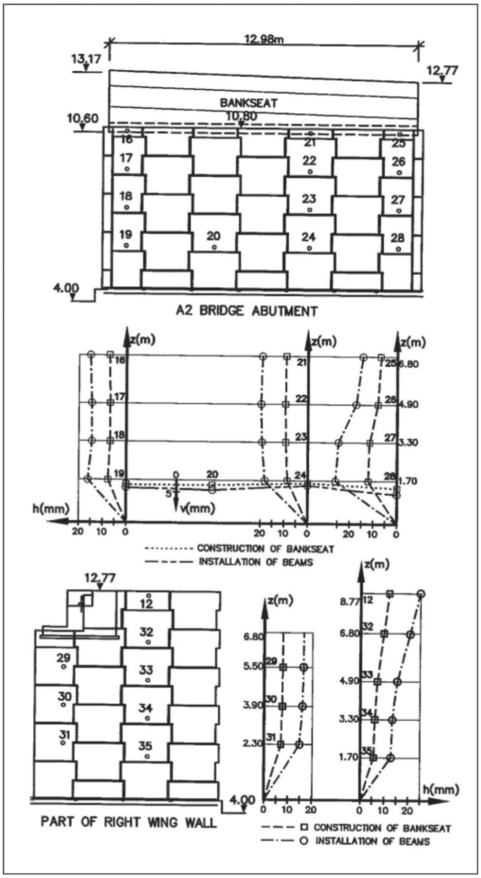

Figure 4. Deformations measured on the A2 abutment on K2A Junction.

5 DISCUSSION

5.1 *Comparison with previous work*

It is normal to expect some sort of deformations in "PRS" structures because of their flexible nature. Usually this deformation can be predicted based on the type of fill used and compaction equipment. The deformations can be compensated with an initial batter given to the panels during installation. Most of the deformations occur during compaction.

However in bridge abutments an additional load from the bankseat and the beams are applied to the structure. External factors like the sequence of beam installation may effect the deformations obtained in bridge abutments. Therefore it is normal in such cases that the panels may move more than the initial batter they have been given during installation.

Brady (1987), reports deformations in the range of 45 mm at a bridge abutment constructed in Camarthen using exactly the same type of polymer strips. This was the first bridge abutment constructed in the UK using polymer strips. A very intensive test program including the measurements of settlement, pressure and tension force was carried out.

The deformations of the panels on a bridge abutment constructed using geogrid reinforcement, reported by McCaul & Snowdown (1990), reached 20 mm after the abutment was opened to traffic.

Balzer et al. (1990), constructed a test wall using needle punched non woven geotextile as reinforcement and loaded the wall until failure. The deformations of the wall was in the range of 15 mm to 25 mm.

Schlosser et al. (1993), report a two phase full scale test wall constructed using Fontainebleau sand. In phase one the deformation of panels during construction were monitored and reached 40 mm. In the second phase the wall was loaded with the aid of vertical ground anchors modelling an abutment, additional panel deformations after construction are in the range of 20 mm to 30 mm.

The maximum deformation measured at point no. 12 (25 mm) is out of the loading range. It has been concluded that this might be due to an external cause or an erroneous reading. Other values obtained on all points are consistent with similar test structures.

The intention in monitoring points no. 19, 20, 24, 28 was to measure the settlement of the base panels. However it was impossible to target the base of the wall from the total station, these points were located above the first horizontal joint. After the evaluation of the results it has been concluded that the settlements measured are actually the compression of bearing pads installed at the first horizontal joint.

5.2 *Observations*

The abutments constructed on areas reclaimed from the sea settled in the range of 15-78 mm. These settlements were not monitored but happened to appear during the construction of the bankseat. By adjusting the height of the bearing blocks, beams were installed at their design levels.

No compressible soils were present at the foundation. However the area where the abutments were built was reclaimed from sea. Due to the wave action, until the rubble mound protection and the fill behind where the abutment sits, takes its final shape, the settlement of the fill is inevitable. The fill for the reinforced soil abutment is compacted properly it is unlikely that the fill will settle. Any settlement occurring at the foundation level will be transferred to the reinforced fill and bankseat at the same time. Therefore no bumps will occur at the entrance to the bridge as is the case with classical reinforced concrete bridge abutments.

Visual inspection of the bridge abutments and retaining walls under traffic loads gave no indication of further deformations.

6 CONCLUSIONS

"PRS" bridge abutments constructed on areas reclaimed from the sea on the Black Sea Coastal Road Project performed extremely well due to the flexible nature of the "PRS" structures.

Monitored deformations of the panels proved that the method of construction adapted for the initial batter of the panels during installation is satisfactory.

Deformations measured during the construction of bankseat and installation of the beams which are in the range of 15-25 mm show similarity with previous work.

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