PERFORMANCE AND DESIGN OF POLYMER REINFORCED SOIL WALLS IN MINE INDUSTRY

Hakan Ozcelik[1]

[1] *EAST Construction and International Trading Co. Inc.. (e-mail: hakan@east.com.tr)*

Abstract: The wing walls for the ramp of two mine crushers were designed using a polymer reinforced soil wall system. The crushers having a height of 22.5m and 16m were located in the west of Turkey, where the horizontal ground acceleration (a/g), should be taken as 0.4 according to the national codes. The walls are subjected to a truck load of 250 tonnes during their service lives. The 22.5m high wall was constructed in 2005 and the other one was intended to be constructed towards the end of 2007 however because of ongoing procedures involving bureaucracy, during the time of this paper was written, the construction has not been started. Visual inspection of the wall carried out after being in service for two years was perfect. Part of the 22.5m high wall included a 6m berm in order to reduce the costs and incorporated stairs for the access to the control unit of the crusher. The fill used was a very coarse ballast type material having maximum particle size of 300mm. The grading curve falls outside the envelope of the fills that have previously been used for the polymer reinforced soil wall system. The 16m high wall is directly subjected to horizontal forces through a concrete slab, modelled as a bank seat beam, while the trucks are dumping ore to the crusher. A fill reinforced with geogrids was designed under the slab in order to increase the friction between the slab and the top of the reinforced soil wall. Flexible nature of the polymer reinforced soil wall system enabled an economic design and a fast construction time.

Keywords: Mining, polymer, reinforced soil wall, seismic design, soil reinforcement

INTRODUCTION

The wing walls of the two mine crushers located in west of Turkey, 1st degree earthquake zone, were designed using a polymer reinforced soil (PRS), wall system. The wing walls required for the first crusher wall (Figure 1), at Kisladag reaches a height of 22.5m and was designed for a horizontal ground acceleration, a/g=0.4 as well as for a live load of trucks carrying mine ore weighing 250 tonnes. Under these design criteria it is obvious that a classical retaining structure will be uneconomical. As an alternative and economical solution, it would be appropriate to use polymer reinforced soil "PRS" wall system for the construction of the wing walls on both sides of the crusher. These wing walls reach a height of 22.5m immediately next to the crusher and then divided into two walls, top and bottom having heights of 10.5m and 12m respectively with a 6m berm in between. The top wall of the wing wall located at the right hand side of the crusher also incorporated stairs enabling the access for the operators to the control room situated at the top of the crusher. The trucks are running parallel to the wing walls and dumping ore into the crusher.

The second crusher wall at Caldag, is a single 16m high wall designed for a loaded truck weight of 100 tonnes. In this crusher the trucks are running perpendicular to the wall and dumping the ore from a dump slab located on the top of the wall. In the design the wall is considered as a bridge abutment and the dump slab is modelled as a bankseat. A 100x100kN geogrid was introduced under the dump slab in order to resist the high horizontal impact loads during breaking by increasing the friction between the dump slab and the top of the "PRS" wall in both directions. The design of the wall has been approved by the consultant however the construction scheduled for the end of 2007 have not commenced yet because of ongoing procedures involving bureaucracy. Therefore only the design of the wall shall be the subject of this paper.

Figure 1. Wing walls of the crusher wall, H=22.5m.

THE "PRS" WALL SYSTEM

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 (Figure 2). Polypropylene dowels, joint filler, EPDM bearing pads, rear fixing bar are the accessories used during the construction.

Precast concrete panels holding the fill behind are 15cm thick and have a surface area of 3.20m^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 connect the strips to the panels. Provided that the toggle bar is equal to or greater than 25mm 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, preferable granular having a minimum internal friction angle ϕ=34º, with material passing No:200 sieve shall be less than 15% and maximum particle size limited to 250mm.

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. This batter depends on the type of fill and compaction equipment used. External factors like the sequence of beam installation may affect the deformations obtained in bridge abutments which are in the range of 15-20mm (Özçelik 2006). 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. The 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.

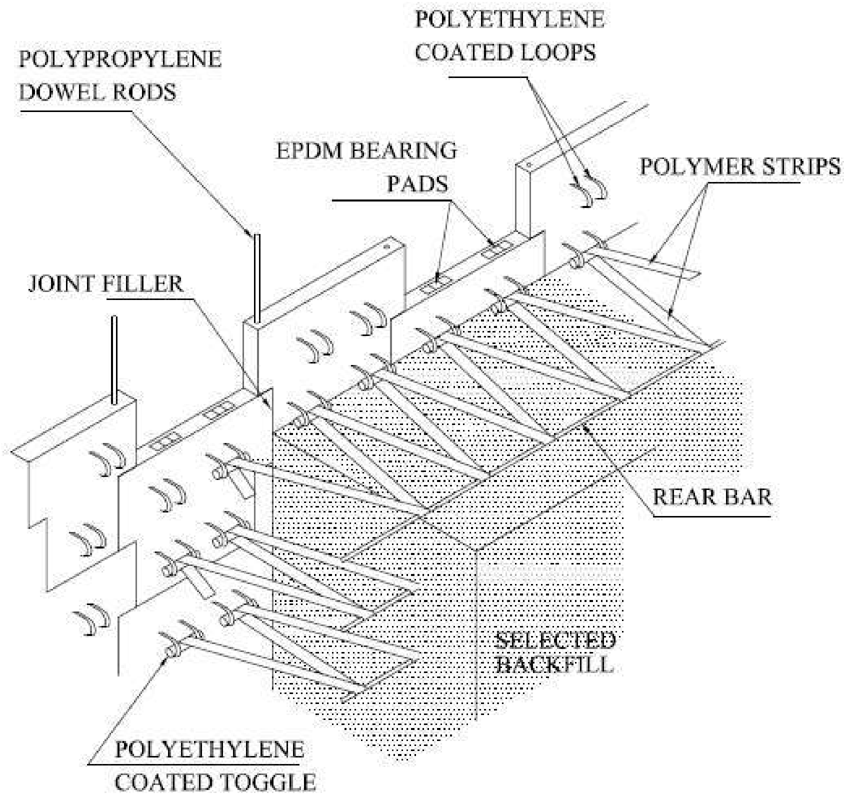

Figure 2. Elements of the "PRS" Wall System (Price & Özçelik,1994)

Properties of the polymer 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^{TM}". There are mainly four grades (30kN, 50kN, 75kN and 100kN) of the polymer strips that are used for soil reinforcement. The polymer strips are delivered to site in 100m coils, after the coils are unwrapped (Figure 3), the strips are connected to the panels and are laid continuously in a zig zag form. The slack of the strips is removed and the strips are laid taut on the fill ready for a layer of fill. The fill should be spread parallel to the panels starting from the back of the strips (Figure 4). The polymer strips in the "PRS" walls are designed to less than 45% their breaking load. The load in the strip 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).

Figure 3. Unwrapping the coils and connecting the strips to the panels

Figure 4. Laying the strips in a zig zag form and spreading the fill.

DESIGN METHOD

The design method of the "PRS" wall consists of external and internal stability calculations. External stability calculations, similar to classical retaining structures, include the checking of factors of safety against sliding at the base, overturning, bearing capacity and global stability analysis. In internal stability, the breaking and pull-out loads of the reinforcement strips define the length and the required number of the strips.

For the Kisladag crusher, the client has provided the below parameters for the fill;

γ = 20.0 kN/m^3 **c = 0.0 kN/m^2** **ϕ = 32°**

Design calculations were carried out according to the French standard NF P 94-220-0 (1998), using **a/g=0.4** and **250 tonnes** truck load on top of the wall. During the operation of the crusher, the fill shall be subjected to severe vibrations which are considered as additional horizontal ground acceleration (**a/g=0.1**). After the designer inspected the fill material on site and decided that **ϕ=35º** will be an optimum choice, hence the calculations were verified with **a/g=0.5** and **ϕ=35º.**

During the design of the Caldag crusher, the 10m long dump slab was modelled as a 5m wide bankseat. The following parameters were used for the fill:

γ = 20.0 kN/m^3 **c = 0.0 kN/m^2** **ϕ = 36°**

The general fill is considered to have an internal friction angle of **ϕ = 33°**. The impact load at the wheels on the 1085mm cantilever section is considered as a 70.5kN/m horizontal load. In order to prevent the cantilever section of the slab sitting directly on the panels a 400mm thick concrete was introduced under the slab. The top layer polymer strip obtained from the calculation was replaced with a 100x100kN geogrid in order to resist high impact loads during breaking by increasing the friction between the dump slab and the top of the "PRS" wall in both directions.

FILL MATERIAL

Grain size distribution of the fill material

The sieve analysis results of the fill material are presented in Table-1 and the corresponding grain size curve is shown in Figure 5.

Table 1. Sieve analysis of the fill material

Sieve opening (mm)	% Passing
600	92
280	64
150	41
75	22
25	16
6.3	8.5

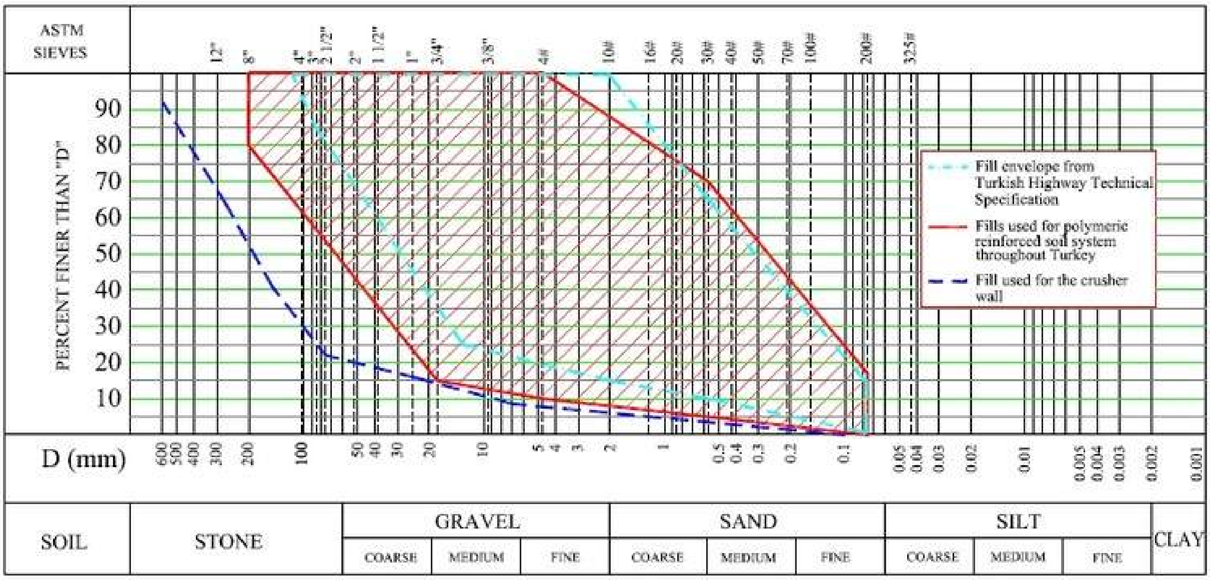

Figure 5. The fill envelope for the “PRS” wall system and the grain size curve of the fill material

Figure 5, also shows the envelope of the fills that have been used for “PRS” walls in various jobs throughout Turkey and the present fill envelope according to the Turkish Highway Technical Specification. Although the grain size distribution curve of the fill material falls outside of the envelope of the fills that have been used in the past, the fill was accepted for the following reasons:

i) Service life of the wall is maximum 15 years
ii) The grain size curve falls on the coarser side of the envelope
iii) Particles greater than 300mm shall be screened
iv) Spreading and compaction of the fill together with the erection of the panels shall be carried out by the wall specialist company who is also the designer.

Compaction of the fill material

The fill having maximum particle size of 300mm (Figure 6), have been compacted in layers of 400-450mm with a Vibromax vibrating compactor having a dynamic load of 36 tonnes. Immediately behind the panels a 1m thick crushed stone filter layer was formed. The control of compaction was done according to the method outlined in Demirel et. al. (1991). In this method, the total settlement at each layer after the last two passes of the vibrating compactor shall be less than 10mm. At the beginning of the construction the first four layers were checked with a levelling instrument. It has been found out that the total settlement after the 4th and 5th passes of the vibrating compactor is 6-10mm. Therefore it has been decided that the vibrating compactor should pass 6 times. Random checks were performed after the 5th and 6th passes on subsequent layers and it has been confirmed that the total settlement is less than 10mm.

PERFORMANCE OF THE WALL AND THE STAIRS

The wing walls are in service for more than two years. The wall is functioning well and fulfilling its intended purpose. The stairs that enable the operators to reach the control room situated at the top of the crusher are incorporated within the right hand side wing wall. Previously steel stairs which are attached to the crusher itself were used for the access to the control room. As the vibrations created by the crusher are also felt on the steel stairs, accessing the control room was an uncomfortable task. However, the present stairs are built within the fill therefore most of the vibrations are absorbed by the fill enabling a comfortable and safe access to the control room.

Figure 6. Fill material used for the crusher wing walls

SUMMARY AND CONCLUSIONS

Two high crusher walls which are subject to truck loads up to 250 tonnes situated in an earthquake zone where the horizontal ground acceleration a/g=0.4, are designed by using “PRS” wall system. The following summary points are made in relation to this particular project:

1. “PRS” wall system have proven to be an economical, reliable system for high mine wall applications, with materials that meet the demands of greater loading while maintaining flexibility and ease of construction.
1. In designing high walls, dividing them into two separate walls by placing a berm in between, not only eases the construction but brings a lot of economy as well.
2. Fill material used for the crusher wall had a grading curve falling outside of the limits defined by an envelope therefore precise care given to compaction and the wall was erected within the tolerances.
3. Although the fill material used had a maximum particle size 300mm, the highest section H=22.5m (Figure 7), of the wall next to the crusher was constructed with nearly zero tolerance and erected completely at the plumb line.
4. Even though the walls were high and had a complex geometry next to the crusher, because of the flexible nature of the “PRS” wall system stairs were easily incorporated within the wall enabling access to the control room.

Figure 7. The highest section H=22.5m of the “PRS” wall next to the crusher

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