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REINFORCED SOIL WALL “EL DERBY”

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ABSTRACT

The improvement of transportation systems is extremely relevant in the development of a city and its life quality. The Lima municipal government aimed to recover the right-of-way of the main highways. Hence, an auxiliary road, occupied by the “Jockey Club”, was used for the construction of the new “El Derby” RI (Road Interchange).

During the peak-hour, the existing road interchange has 8% of the average total traffic volume. Moreover, the reduction in the level of service is due to qualitative factors such as the reduction of the lane and the high density of the vehicles. Similarly, the proposed road interchanges have no grading because space is a concern. Hence, the reinforced soil system was opted.

The reinforced soil system wall has concrete segmental panels as facade and it is reinforced with polymer straps that render the structure stable.

1. INTRODUCTION

1.1 Study Area

In the city of Lima is located the Panamericana Sur Road, which links different districts such as: Ate, La Molina, San Borja and Santiago de Surco.

At km. 04 of the Panamericana Sur is located “El Derby” Road Interchange, at an approximate altitude of 164 to 182 m.a.s.l. with a warm and humid climate, having low fluvial precipitations.

Also, the reconstruction of the RI (Road Interchange) "El Derby" is located between third party land on the east side; while on the west side, with a family condominium.

1.2 Justification and Importance

The main objectives of the reconstruction of the RI (Road Interchange) "El Derby" are the following:

- Recovery and expansion of rights of way occupied by third parties, which will lead to better flow of traffic at peak-hour, improvement of accesses and reduction of limitations of vehicle transit.
- Improvement of vertical clearance, since it is insufficient for heavy vehicles, generating accidents and insecurity for citizens.

For this reason, it was decided to opt for a road solution, this being the reinforced soil wall contained with concrete panels. Reinforced soil walls are basically made of soil and high performance synthetic elements. The main function of the linear reinforcement is to absorb the tension efforts and minimize the deformations. The reinforcements must cross the possible failures so that they can mobilize the resistance and increase the safety factors.

2. BACKGROUND

In 2012, a large vehicle hauling a concrete mixer got stuck under the RI (Road Interchange) "El Derby", causing intense traffic congestion. This was due to the vertical clearance, which did not meet the minimum requirements for separation with the wearing course.

Picture N°1. Accident in road interchange “El Derby”.

Source: https://rpp.pe/lima/actualidad/camion-con-mezcladora-de-cemento-se-atora-en-el-puente-el-derby-noticia-469996.

3. CHARACTERIZATION OF THE STUDY AREA

The RI (Road Interchange) "El Derby", is located in the area of Rimac River’s alluvial deposits, which origins date from the Pleistocene period.

3.1 Geomorphology

The RI (Road Interchange) "El Derby", runs through minor geomorphological units that have been originated by cumulative and erosive processes. The agents that initially acted in its formation correspond to the quaternary system through the action of flooding flows of fluvial and marine origin, as well as rock weathering from the adjacent hills, while in a more recent stage the acting agents have been the action of coastal winds and gravity.

3.2 Local Geology

The city of Lima is located on the Quaternary alluvial fans of the Rimac, Chillón, and Lurín Rivers framed by sedimentary rocks from the Upper Jurassic to Lower Cretaceous and intrusive rocks from the Andean Batolito (Upper Cretaceous - Lower Tertiary).

- Pamplona Formation (Ki - Pa)
  It is a stratigraphic sequence composed of limestone, marl, siltstone and shale; this geological formation is characterized by abundant limestone strata.
- Alluvial deposits (Qp - al)
  Composed of gravel, sand, silt and clay.

Road interchange "El Derby" is located in the area of alluvial deposits from the Rimac River that originated in the Pleistocene period.

3.3 Geotechnical Campaign

In order to analyze and quantify the soil’s physical and mechanical characteristics, the following geotechnical investigations were carried out:

- 8 test pits between 1.5 and 5 m deep.
- 4 SPT boreholes between 20 and 25 m deep.
- 3 seismic refraction tests and MASW probing.

3.1 Geotechnical Parameters

Altered (MAB) and unaltered (MIB) samples were obtained for the soil mechanics study, which includes the following tests:

- Modified Proctor.
- Chemical Tests (Salts, Chlorides and Sulphates)
- Direct shear
- Granulometric Analysis

3.1.1 Soil Stratigraphy

In the subsoil of the RI (Road Interchange) "El Derby" there are 3 stratigraphic units which are described below:

In the most superficial layer, with a thickness of approximately 2.00 m, there is a covering material formed in its essence by sandy silt with a low presence of gravel.
Below this layer, there is a second unit with a thickness of approximately 5.50 m made up of a proportion of sub rounded gravel of 3" in maximum size, wrapped in a sandy matrix.

Finally, from a depth of 6.50 m downwards, the third unit is found, which consists mainly of a material similar to that of the Rimac River's alluvial compacted deposits, called conglomerate, formed by dense gravel with a maximum size of over 3", wrapped in a sandy matrix, with medium compaction.

4. REGULATIONS

For MSR evaluations, the following standards with similar and different considerations apply.

4.1 AASTHO – LFRD

The methodology proposed by AASTHO is the LRFD (Load and Resistance Factor Design), in which it distinguishes the variation of applied loads and resistant loads in the safety factors.

Likewise, for an Reinforced Soil Wall (RSW) design, different loads and load factors, as well as their combinations, must be considered.

- Permanent loads: EH (horizontal earth loads), ES (earth surcharge load), EV (vertical dead load pressure - fill)
- Transient Loads: EQ (Seismic Loads), CT (Vehicular Collision Force), LS (Live Load Surcharge), LL (Live Vehicle Load)

Stability Mode	**Condition**	**Resistance Factor**
Bearing Resistance		0.65
Sliding		1.00
Overall (global) Stability	Where geotechnical parameters are well defined, and the slope does not support or contain a structural element.	0.75
	Where geotechnical parameters are based on limited information, or the slope contains or supports a structural element.	0.65

Table 1. External Stability Resistance Factors.

Source: The Federal Highway Administration, FHWA (2009).

Load Combination Limit State	EH ES EV	LL LS	Use One of These at a Time	
			EQ	CT
Strength I	γ_P	1.75	-	-
Extreme Event I	γ_P	γ_{EQ}	1	-
Extreme Event II	γ_P	0.5	-	1
Service I	1	1	-	-

Notes:
γ_P: load factor for permanent loading. May subscript as γ_P - EH, γ_P - ES, γ_P - EV, for EH, ES, EV.
γ_{EQ}: load factor for live load applied simultaneously with seismic loads.

Table 2. Wall Load Combinations and Load Factors

Source: The Federal Highway Administration, FHWA (2009).

4.1.1 *External Stability*

The resistance factors in the external stability analysis are presented below, taking into account that the structure itself is made of reinforced filler material.

Type of Load	Load Factor	
	Maximum	Minimum
DC: Component and Attachments	1.25	0.9
EH: Horizontal Earth Pressure - Active	1.5	0.9
EV: Vertical Earth Pressure - Overall Stability - Retaining Walls and Abutments	1 1.35	N/A 1
ES: Earth Surcharge	1.5	0.75
Note: May subscript as γ_{EQ-MAX}, γ_{EV-MIN}, γ_{EH-MAX}, γ_{EH-MIN}, γ_{ES-MAX}, γ_{ES-MIN}		

Tabla 2. Permanent Load Combinations

Source: The Federal Highway Administration, FHWA (2009).

4.1.2 *Internal stability*

The verification of the preliminary dimensioning for internal stability of the Reinforced Soil Wall (RSW), where the resisting force is less than the shear resistance along the wall.

It is interpreted as the force that transmits the slide being the horizontal component of the active earthwork. It should be noted that the transient load is not considered as a force that prevents the slide.

4.1.3 *Eccentricity limit*

The verification of the eccentricity limits takes into consideration the structure's weight and the front wall's width.

The value of the eccentricity is determined by performing the sum of the tilting and resistance moments at the center of the base, and dividing it by the acting vertical forces.

4.1.4 *Bearing resistance*

The verification by bearing resistance considers two mechanisms of foundation soil failure:

- General failure by shear, for its prevention it has to be ensured that the increased vertical pressure does not exceed the reduced resistance of the foundation soil.
- Local shear failure is generated in cases of soft or loose soils below the reinforced soil wall.

The seismic evaluations are analyzed in a similar way to the static methodology, except in the establishment of the dynamic effects on the Reinforced Soil Wall where an inertial force must be incorporated which is determined by the product of the horizontal seismic coefficient and the mass of the active zone.

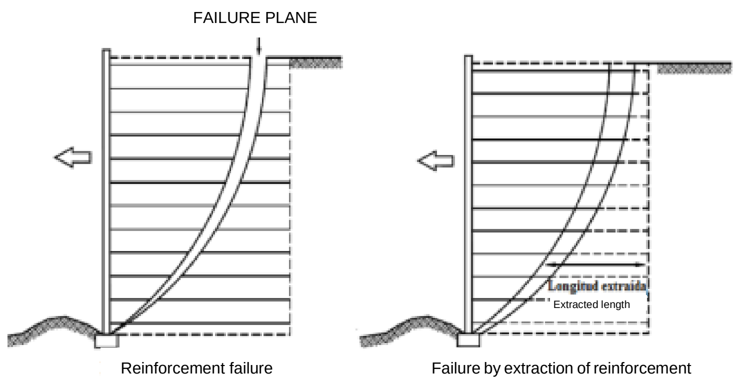
4.2 FHWA – National Highway Institute

The proposed methodology by the FHWA is the ASD (Allowable Strength Design), in which the uncertainty of the applied and resistant loads is reflected in a Safety Factor (SF).

On the other hand, the dimensioning of the reinforcements is based on an admissible stress, which uses the uncertainty in the variation of the applied loads and in the initial resistance of the reinforcement.

4.2.1 External Stability

The external stability assessment evaluates four (04) possible failure mechanisms: Base sliding, toppling failure, bearing resistance and global stability.



Picture N°2. Failure mechanisms - external stability

Source: Deslizamientos: Técnicas de Remediación, Suárez, J (2009).

4.2.2 Internal Stability

Internal stability failures can occur in two different ways:

- Failure due to breakage of the reinforcements, where the shear forces have become so great that the reinforcements break, resulting in large displacements or collapses of the structure.
- Failure by tearing, where the tensile forces are much greater than the resistance and result in large displacements.

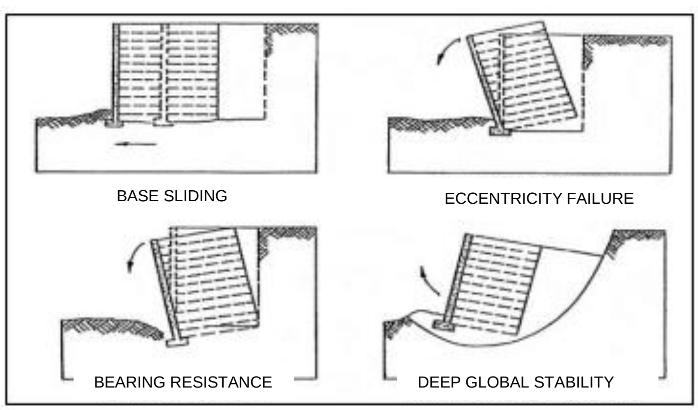


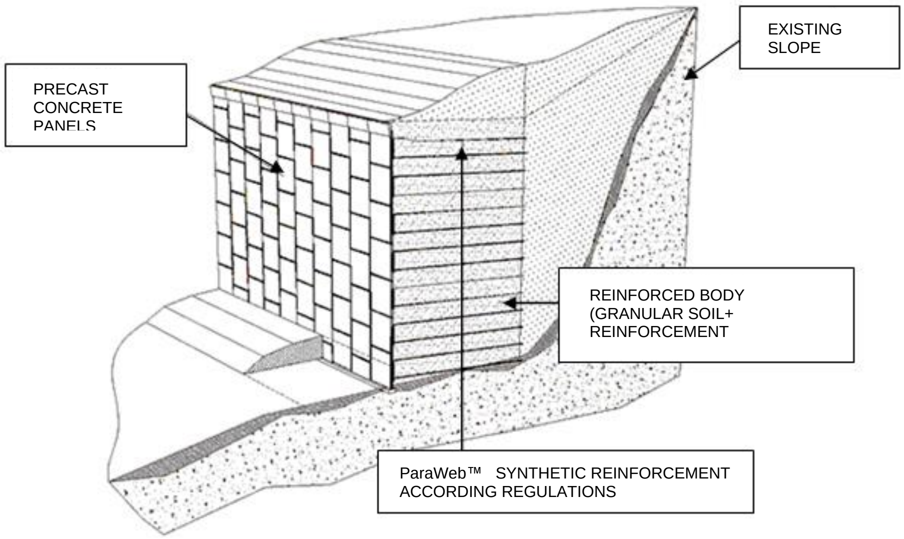
Figura 3. Failure mechanisms - internal stability

Source: The Federal Highway Administration, FHWA (2001).

5. ENGINEERING SOLUTION

Once the justification and necessity were understood, it was considered an engineering solution.

Reinforced soil walls are made up of soil and reinforcement elements inserted into the soil. The main function of the reinforcement is to absorb tensile stresses and minimize deformations. The reinforcements must cross possible plane failures so that they can mobilize their resistance and increase the safety factors.



Picture N°4. Typical Reinforced Soil Wall Diagram

The components of the RI (Road Interchange) "El Derby" Reinforced Soil Wall are described:

5.1 Precast Concrete Panels

The precast concrete panels used for the system may have either a smooth or a textured face, and dimensions of the panels are variable depending on geometry.

The concrete panels must have a minimum resistance to compression of 35 MPa within 28 days and have a block - paraloops connection system, these are made up of polymeric tape and a plastic head that fulfills the function of holding the ParaWeb tapes. The number of connection systems per panel will depend on the required tensile strength.

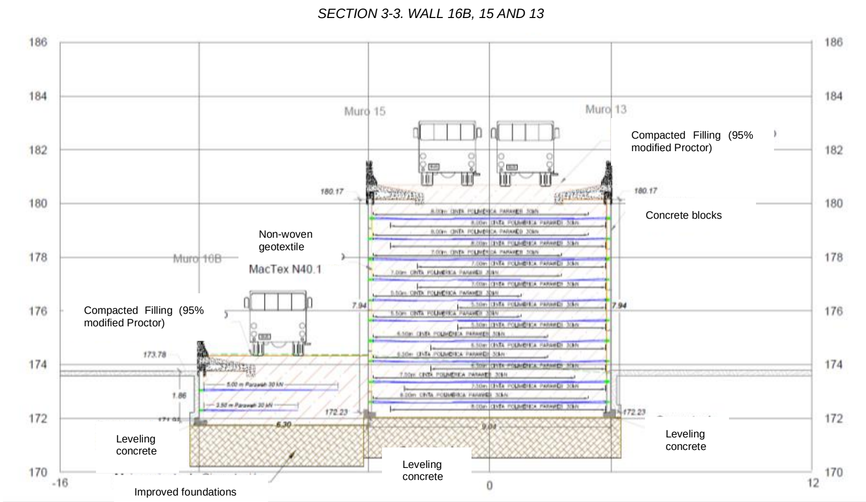
5.2 Polymer Tapes

Polymer tapes are polyester tapes made from high-tenacity polyester multifilaments that are coextruded with a polyethylene coating with a high strength value.

5.3 Granular Compacted Filler

The space between one strip and another must be filled with a selected material, this material directly influences the wall stability and construction progress.

Sand and gravel are typical fillers for this type of structure, since they are more easily compacted than soils with high presence of clay or silt; plus, they have good permeability.
Having understood the RI "El Derby" Reinforced Soil Wall components, we present the typical sections, which consist of a Back to Back wall and an overlapping wall and have a critical height of 8.70 m.



Picture N°5. Typical Section of a Back to Back with overlapped wall.

Source: Own Elaboration.

6. CONSTRUCTION

Between January and March 2019, construction of the “El Derby” RI (Road Interchange) Reinforced Soil Wall was carried out. Reference picture is shown down below.

Picture N°6. Construction of the Reinforced Soil Wall – RI (Road Interchange) “El Derby”

Source: Own Elaboration.

Currently there is free transit on the RI (Road Interchange) "El Derby", which benefits more than 400 thousand people who circulate daily in the area, crossing the districts of Santiago de Surco and San Borja.

Picture N°7. Reinforced Soil Wall – RI (Road Interchange) “El Derby”

Source: https://elcomercio.pe/lima/obras/el-derby-abren-nuevos-viaductos-pero-intercambio-vial-aun-esta-al-78-panamericana-sur-municipalidad-de-lima-intercambio-vial-noticia/?ref=ecr.

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