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Reinforced soil structure trench with geogrid and head wall using interlocked concrete blocks

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ABSTRACT: The paper presents a case of site construction of reinforced soil structure trench, which is being constructed at Maringá City, Paraná State in Brazil. An important characteristic of Maringá City is the existence of railway crossing downtown, which results in transit conflicts. To solve these problems a railway lowering promoting interaction between urban plan and landscape design with the adjacent areas was proposed. The design geometrical characterization was a consequence of the new topographical situation at the local site, which demanded 2,964.4 m of a trench soil digging contention, totalizing 5,928.8 linear meter of almost vertical contention wall, performing 5 to 12 m heights. Aiming to combine beauty, cutting-cost and quickness at execution, a Reinforced Soil Structure Trench with Geogrid and Head Wall using Interlocked Concrete Blocks was chosen. This structure must be able to support the viaducts for cross-roads, lateral highways, gardens, walkways and drainage works, and guarantee citizens and Railway user's security.

1 INTRODUCTION

Maringá is a city planned since its establishment in 1947. Due to the need of transporting source through northern State, a railway was inserted in the central axis of the city, crossing a great urban area. This railway crosses the central area of the city in East-West direction, sectioning almost the entire urban central area

With population and traffic increasing, the accidents in the downtown cross-roads, several of them built at the same railway level, started to happen.

In order to avoid this kind of problem and incorporate the railway into the urban space, the technical staff of Maringá City Hall decided to lower the railway. To accomplish this, they contracted a project entitled "Railway Lowering", which one of the stages is the design of a contention structure in trench, having also for goal the support of viaduct that will be inserted in the existing cross-roads.

Amid proposed solutions considering several applicable contention techniques, the solution of Reinforced Soil Structure Trench with Geogrid and Head Wall Using Interlocked Concrete Blocks was chosen to be the most economical and quick made.

The current paper has the goal of describing this structure design and presents a brief description of the execution mode.

2 DESIGN PREMISES

Maringá is located in Paraná State, southern region of Brazil, having been settled by citizens from São Paulo, Paraná, Rio Grande do Sul States and Brazilian North-eastern area and also migration movements of European and Asian people, remarkably from Japanese ethnics. Table 1 shows physical and geographical characteristics of the city.

Table 1. Physical and geographical city characteristics.

Location	Latitude	23° 27′ S
	Longitude	051° 56′ W
Area	473.064.190 m^2	
Altitude	Between 500 and 600 m above sea level	
Weather	Subtropical, with rainy season and dry winter.	
Average temperature	21°C	
Population	303.551 inhabitants (data from IBGE/2003 – Brazilian Institute of Geography and Statistics)	
Green Area	27 m^2 of green area per habitant	

Source: http://www.maringa.pr.gov.br

The railway crossing the central area can be seen at Figure 1. Considering the problems caused by the cross-roads at railway level, the technical staff of

Figure 1. Railway crossing the city in East-West direction.

Architects, Urban planners and Engineers, decided to lower the railway, through a new urban proposal.

To accomplish this, Maringá City Hall bid the engagement for a project named *Lowering the Railway*. The winner company of bidding process to accomplish the project was Vega Engineering and Consulting (Vega Engenharia & Consultoria) and the Reinforced Soil Structure Trench along the railway design is one of the stages of this project.

The Reinforced Soil Structure Trench with Geogrid and Head Wall Using Interlocked Concrete Blocks design has as main goals:

- support the viaducts for cross-roads;
- support the already existing lateral ways, the insertion of new lateral ways, gardens, walkways and drainage works;
- guarantee the safety of Railway and Highway users;
- allow the perfect enchasing of defences over the wall crest, in order to avoid the access of vehicles and pedestrians over the limits of railway, and
- allow a perfect interaction between urban areas.

Moreover, for being an urban area of the city, with great traffic of cars and pedestrians, build equipments circulation could be a problem. These facts evidenced the need to choose a technique that utilize the soil of the project area insertion and above all, would be easily, quick and cheap executed and also aggregate urban value for the city.

The technical staffs of Main Hall of Maringá have evaluated technical and economical viability of several proposed solutions to contain the lateral trench. Veja Engineer purposed as solution a Reinforced Soil Structure Trench with Geogrid and Head Wall Using Interlocked Concrete Blocks enabled to be accomplished with quickness, economy and cleanness, donning a soil structure able to support bridges and viaducts.

3 GEOMETRICAL CHARACTERISTICS AND CONSIDERED PARAMETERS

Trench lateral walls are almost vertical along the lowered sectors of railway, leaving a lowered band of 14 meters. The sector where has been inserted the reinforcing soil structure is presents two segments:

- The East sector performs 1,880 m in trench, which means 3,760 m of reinforced soil structure with 8.2 to 11.9 m height faces, having 95 transversal cross-sections evaluated;
- The West sector has 1,084.4 m of trench, which means 2,168.8 m of reinforced soil structure with heights varying between 5.1 to 10.0 m and 56 cross-sections were evaluated.

Amid the evaluated cross-sections 8 cross-sections at 5 to12 m of height were chosen.

Soil characteristics in the lowering railway work area are very good, not presenting trends to collapses or erosions, mainly when well compacted, presenting excellent bearing support characteristics.

The soil possesses 60% in weight of particles passing in bolter #200 having testing results that indicates:

- a total apparent specific weight, γ, of 17 kN/m^3 with an average friction inner angle (ϕ) of 28° in natural condition,
- the same total apparent specific weight with a cohesion, c, of 8 kPa and friction inner angle of 27° after compaction.

Special cross-sections had been considered in the segments in which the soil structure will have the function of supporting viaducts. For these cases it was considered the viaduct structure and the drainage works as a strip load acting directly over the reinforced soil structure.

4 ANALYSIS AND DIMENSIONING OF REINFORCED SOIL STRUCTURE

The length of the reinforcements had been determined considering the external stability analysis for each type section verifying tumbling and sliding risks and soil foundation bearing capacity.

Ehrlich & Mitchel (1994) method was applied to calculate spacing and reinforcements types. This method considers soil parameters (γ, c and ϕ), reinforcement strength, relative materials stiffness and induced loads due to compaction.

Due to soil structure along the trench varies until a height of 11,90 m, the advice during the compaction process is to improve a pre-loading in soil and reinforcement, to get smaller deformations.

The variation of required strength for each height of contention is shown in Table 2.

Table 2. Variation of the required strength.

height (m)	number of layers	spacing between reinforcements (m)	required strength (kN/m)
12	20	0.6	110
11	18	0.6	110
10	16	0.6	80
09	15	0.6	80
08	13	0.6	80
07	11	0.6	55
06	10	0.6	35
05	8	0.6	35

Anchorage length are verified considering interface shear strength parameters as 2/3 of them adopted for soil and a Safety Factor major than 1.13. Figure 2 presents a typical designed section to illustrate the adopted solution.

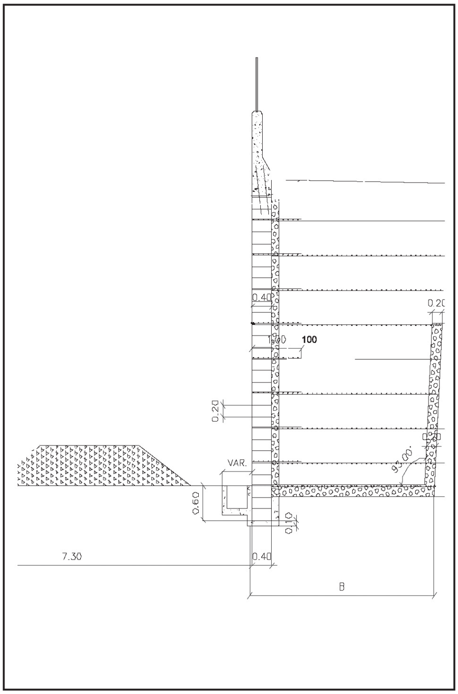

Figure 2. Typical designed section.

Deformation analyses were performed in terms of specific deformations or maximum lengthening during compaction, end of construction and long term period. For these analyses the stiffness behaviour of geogrid were considered for short and long term period, from historical results furnished by manufacturers. For each section type the maximum specific lengthening was obtained for all the reinforced layers considering geogrid behaviour.

The criteria for evaluating deformation followed those recommended by Brugger et al. (2005):

- The compaction energy must be high, so it can mobilize the major portion of deformations;
- The increase of maximum specific lengthening between the end of improvement process and the end of construction must be smaller than 5%;
- The increase of maximum specific lengthening between the end of construction and a long-term period must be smaller than 1%.

For walls supporting bridges and viaducts BS 8006 (1995) recommendation have been considerate and a 0.5% value was defined.

5 BASIC SOURCES

5.1 *Polyester geogrid*

For reinforced soil structure were specified polyester woven geogrids, with high resistance, high module and low creep to guarantee small deformations along the time. The texture opening of geogrid is 2 × 2 cm, which allows a perfect connexion with the block by interlocking with gravel. Considering an expected life of 60 years, and the reduction factors:

- creep: $FR_{CR} = 1.56$
- Installation damage: $FR_{ID} = 1.05$
- Environmental ageing: $FR_{EA} = 1.03$
- Synergy and extrapolation effects: FS = 1.05
- $FR_T = 1.77$,

products with 35, 55, 80 and 110 kN/m of tensile maximal strength were specified to accomplish the several conditions present on this work.

5.2 *Concrete blocks*

Although for heights between 5 and 8 m blocks with minimum compression strength of 6 MPa would satisfy design requests, the specified blocks need present a minimum strength of 12 MPa to easily control construction process.

The main characteristic of the block, Figure 3, is the specific adjusting system, which allows the assembling through adjusting without using concrete or mortar, fulfilled with gravel to guarantee the geogrid connexion and allows water percolation through surface.

The determining fact defined by the technical staff of Main Hall of Maringá to choose block faces was the pleasant aesthetical appearance of the wall.

5.3 *The soil*

For the insertion of trench, due to lowering of the railway, an excavation process is necessary and local soil was employed as filling in reinforced structure, after vegetal layer and cutting materials rejecting.

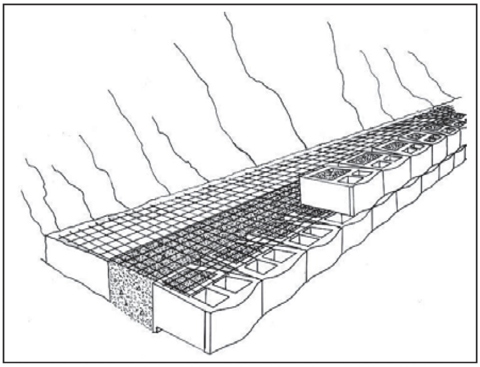

Figure 3. Characteristics of the blocks.

During the accomplishment of walls, the soil is scattered and compacted at optimized water content ($\Delta w < \pm 2\%$) in layers of 0,20 m thickness at 100% of the Proctor Standard maximum apparent dry specific weight. In the zone near to concrete blocks (approximately 1 m) the soils have been improved with manual equipment at 95% of the Proctor Standard maximum apparent dry specific weight.

5.4 *Material for drainage*

The surfaces of blocks assembled only with gravel are drainable enough and dispenses the accomplishment of specific drainage elements.

To guarantee the non-saturation state of the reinforced soil, the insertion of a vertical drainage system at the interfaces between natural and improved soil had been forecast (see Fig. 2). This drain is composed by a layer composed by 0.2 m of pebbles. Near the surface of the wall, in the voids of the blocks, a layer of 0.15 m of gravel was accomplished to guarantee the surface drainage and improve the geogrid connexion to the blocks. In the basis of the walls a drainage tube was inserted in lower points to collect eventual water from the drainage system, with exits.

6 FINAL COMMENTS

The paper presents a field application of soil reinforcing by polyester woven geogrids and face segmented concrete blocks interlocked in a total length wall of 5,928.8 m and maximum height of 11.9 m, where the guarantee of safety towards rupture and the aesthetics characteristics are regarded as very important.

The Reinforced Soil Structure Trench with Geogrid and Head Wall Using Interlocked Concrete Blocks allows accomplishing quickness, cleanness and economic soil structure able to function as contention and support for highway works and bridges and viaducts structures.

The choice of Vertical Hanging in Concrete Blocks affords, after trench accomplishment conclusion, an extremely enjoyable urban and landscape view, so adding tourist value and environmental comfort to Maringá City.

The main factors to choose this type of wall in Maringá was the possibility to utilize the own local soil for accomplishment of compacted landing, allowing that the excavated material in a segment of work could be immediately employed for accomplishment of walls in the neighbours segments.

Once this accomplishment process does not utilize cast concrete at the site, neither need the slow manual assembling of stone walls, its accomplishment is very quick and can be made using fewer workers. In general, the determining factor of accomplishment is only the scattering and compaction of soil layers.

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