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Design and Construction of a 9.6m High Segmental Wall

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ABSTRACT

Reinforced soil walls using metallic reinforcement have been extensively used in Malaysia since 1982. However, geogrid reinforced segmental wall is relatively new in Malaysia. Majority of its applications is found in low height landscaping and retaining walls within gardens. As an exception, a 9.6m high Nehemiah Segmental Wall was designed and built as an end treatment for a long span precast concrete arch culvert underpass. The underpass is part of the Southern Inner Ring Road Project in Putrajaya. The objective of the paper is to provide a case history to illustrate how a relatively high segmental wall is designed and constructed. The paper summarizes the design methodology and construction procedure for the erection of the segmental wall. High tenacity polyester geogrid is used for soil reinforcement. The specification and technical requirements for the reinforcement, modular concrete blocks, and backfill material are elaborated. Some problems were encountered during the erection of the wall. The remedial solution implemented is highlighted. Todate, the segmental wall is found to be performing satisfactorily.

INTRÓDUCTION

In 1982, one of the earliest reinforced soil structures in Malaysia was built using metallic reinforcement. (Chiu, et al. 1987) Since then, numerous reinforced soil structures have been constructed throughout the country. In recent years geogrid reinforced segmental walls have been introduced into the market. However, their applications have largely been confined to relatively low heights. In 1999, a relatively high (9.6m in height) segmental wall was completed at Putrajaya for the Southern Inner Ring Road Project. The segmental wall was constructed over and at the side of an underpass made of three spans of precast concrete long span culverts. The elevation of one of the segmental walls is shown in Figure 1. The height of the wall varies with a maximum of 9.6 m. The details of the system components are explained below, followed by design methodology and construction procedure.

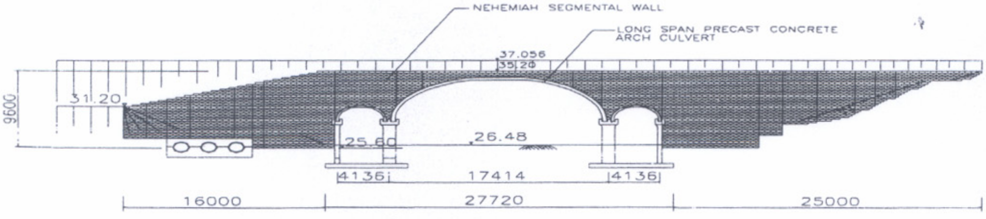

Figure 1: Rear elevation of the segmental wall at Putrajaya

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SYSTEM COMPONENTS

The segmental wall system is made up of the wall facing, geogrid reinforcements and backfill material. A typical cross section of the 9.6 m wall is shown in Figure 2.

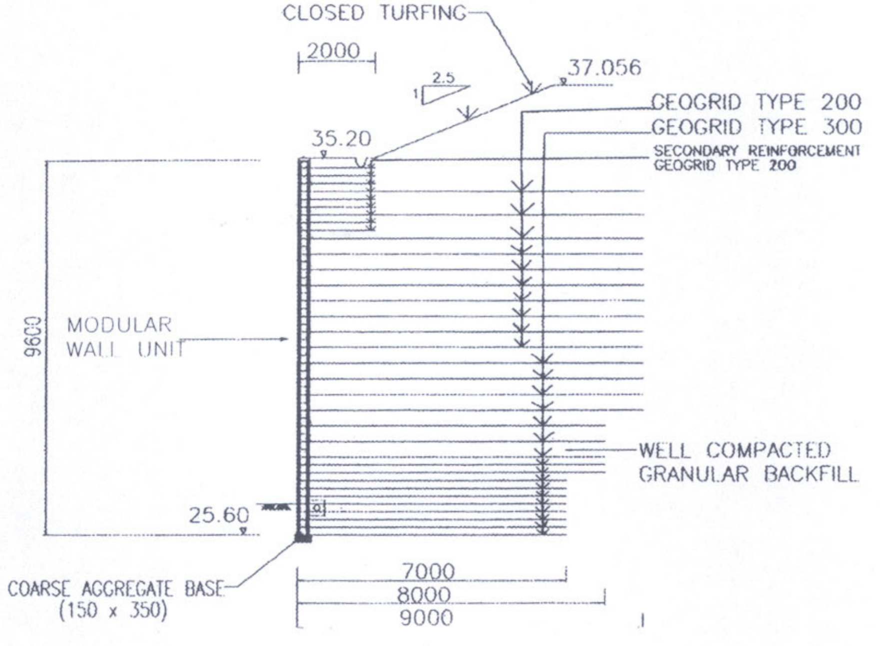

Figure 2: Typical cross section of the 9.6 m high segmental wall

Facing

The facing consists of hollow-core modular concrete blocks dry stacked together. A typical unit of the block is shown in Figure 3. Notice the front lip which provides extra shear resistance between the blocks and allows a constant setback between each block. This constant setback ensures a uniform batter of the facing from the vertical. For this particular project, the setback is zero. In other words, the facing is vertical. There is no batter. The hollow-core in the blocks are infilled with well graded aggregates. The size of aggregates varies from 6 to 38 mm with no more than 10 % passing sieve 200. Thus the facing is free draining. Figure 4 illustrates how the blocks are stacked together and self draining nature of the facing. The 28-day compressive strength of the block is 20 Mpa.

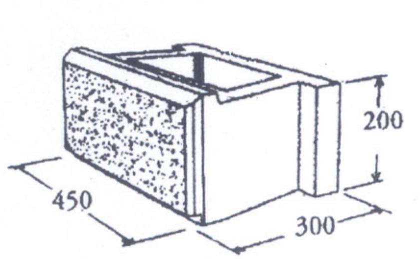

Figure 3: A single hollow-core modular concrete block

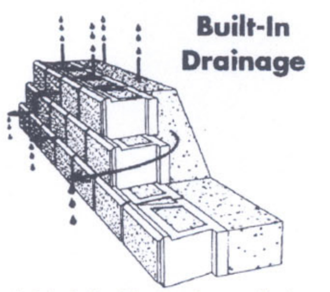

Figure 4: Modular blocks dry stacked together

Geogrid reinforcement

The geogrid reinforcement is made of high tenacity polyester yarn knitted into dimensionally stable uniform network of apertures as shown in Figure 5. The polyester fibers are impregnated with PVC as protection against environmental degradation. The tensile strength properties of the geogrid is shown in Table 1.

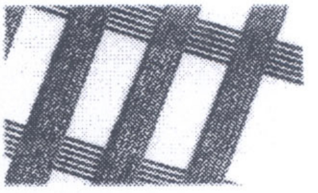

Figure 5: Geogrid reinforcement made of high tenacity polyester yarn

Table 1: Mechanical properties of geogrid

Properties		Test standard	Unit	Type 200	Type 300
Tensile strength	MD* CD**	ISO 10 319 or ASTM 4595	KN/m KN/m	33 25	45 18
Elongation at break	MD CD	ISO 10319	% %	15 13	15 13
Long term design strength		GRI (Drexel University, USA)	KN/m	15.9	21.6
Unit weight		EN 965	g/m^2	340	360
Aperture size	MD CD		mm mm	16 17	15 40

*Machine direction

**Cross machine direction

The long term design strength (LTDS) is determined according to GRI test method, 1993. The LTDS is computed as follows:

$$LTDS = T_{ult} / (FS_{CR} \times FS_{ID} \times FS_{CD} \times FS_{UNC})$$

where

T_{ult} is the ultimate tensile strength

FS_{CR} is the partial factor of safety for creep deformation = 1.54

FS_{ID} is the partial factor of safety for installation damage = 1.10

FS_{CD} is the partial factor of safety for chemical degradation = 1.17

FS_{unc} is the partial factor of safety for material uncertainties = 1.05

Besides the LTDS, the other important engineering properties of the geogrid for soil reinforcement is the interface properties between the backfill material and the geogrid. Based on the large scale shear box test results furnished by the geogrid manufacturer, a value of 0.9 was adopted for the coefficient of direct sliding (Bauer, 1991).

Backfill material

Granular material is used as backfill. In the present case, the backfill material used is quarry dust whose paritcle shapes are angular which provides good frictional properties. The mechanical properties assumed for this material is shown in Table 2.

Table 2: Mechanical properties of quarry dust as backfill material

Backfill Material	Bulk density	Cohesion	Angle of friction
Well compacted quarry dust	20 KN/m^3	0	36°

DESIGN METHODOLOGY

As the reinforcement is considered extensible, the tie back wedge method as described in BS 8006:1995 is adopted. In line with the tie back wedge method, the Rankine earth pressure distribution and failure plane are assumed in the design. However, instead of the limit state approach as advocated in the BS the conventional limit equilibrium approach is adopted. The reason for doing so is that the partial material factors of safety of proprietary geogrid available in the market is still geared towards the limit equilibrium method.

As in any conventional reinforced soil wall, the design procedure involved external stability check and internal stability checks. Additionally, local stability check against facing connection failure and bulging are also checked. The various modes of failure are illustrated in Figure 7. The factors of safety associated with the various modes of failure are shown in Table 3 and 4. A typical cross section of the wall designed to meet all the safety requirements is shown in Figure 2.

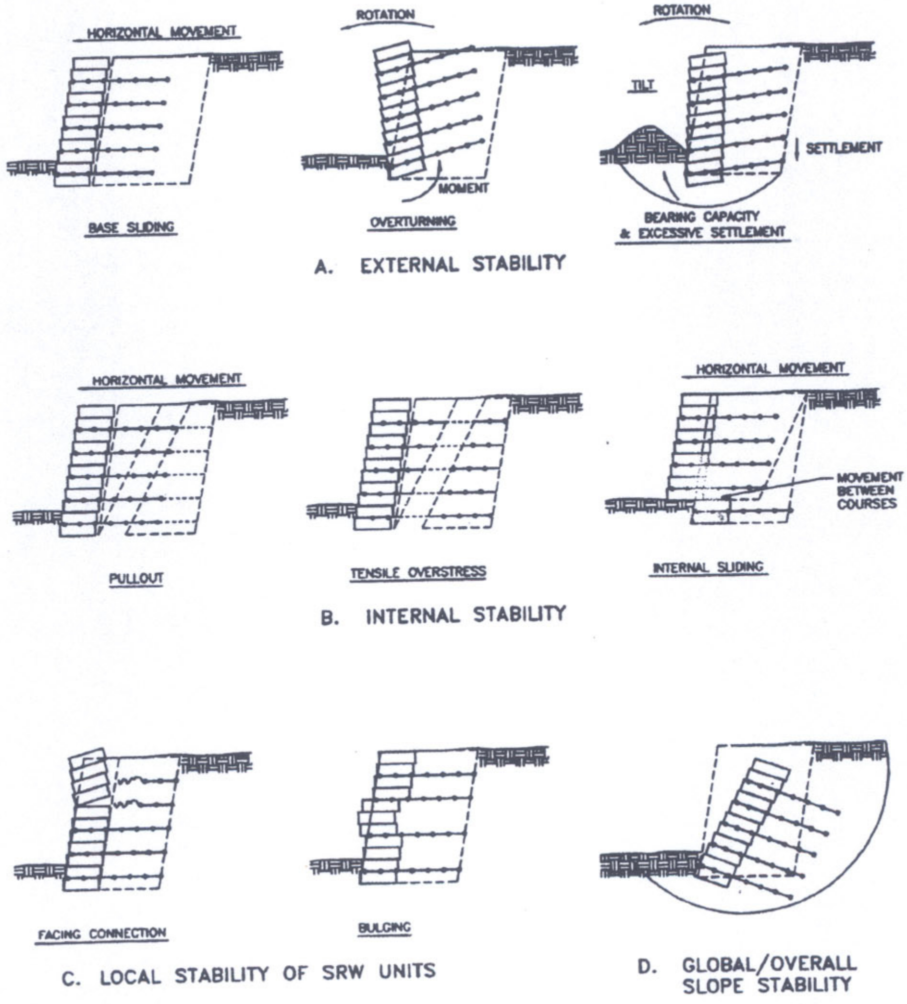

Figure 6: Modes of failure of segmental wall (Simac et al, 1993)

Table 3: Factors of safety for external stability

Mode of failure	Factor of safety
Base sliding	1.5
Bearing	2.0
Overturning	2.0
Global	1.5

Table 4: Factors of safety for internal and local stability

Mode of failure	Factor of safety
Tensile	1.0
Pullout	2.0
Facing connection	1.5
Bulging	1.5

CONSTRUCTION PROCEDURE

Before the commencement of the wall erection, the subsoil condition is verified by Mackintosh probes along the wall alignment. This is to ensure that the subsoil condition is able to meet the bearing capacity requirements and settlement criteria. Any soft material detected was removed and replaced with well compacted granular material. A trench of 350 mm by 200 mm was excavated to receive the base coarse aggregates. The aggregates were compacted and leveled off with a 50 mm thick lean concrete. The base course of modular concrete blocks was then placed along the alignment of the wall with the help of position string. Blocks can be adjusted to form straight lines or smooth curves. The aggregate infill serves to provide a positive interlock between the blocks and at the same time permit the free flow of water through the blocks. The aggregate infill also increases the overall weight of each block.

The granular material is backfilled behind the base course of blocks, spread, leveled and compacted. If plate compactor is used, the maximum thickness of each lift of backfill thickness is 200 mm. For heavier compactor, say 10 tons vibratory roller, a maximum thickness of each lift is 400 mm. Compaction must be carried out along a path parallel to the alignment of the wall and working from the front of the wall to the back of the backfill as shown in Figure 7. All heavy construction vehicles must be kept at least 1.0 m away from the back of the wall face.

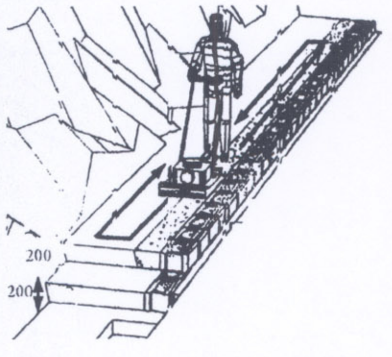

Figure 7: Compaction of backfill

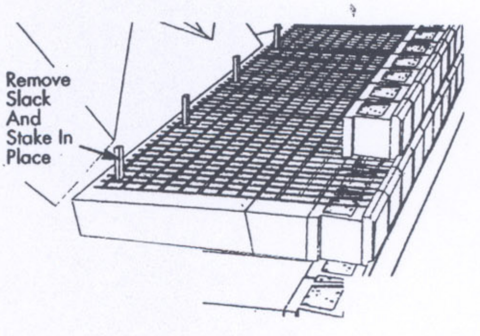

Figure 8: Installation of first layer of geogrid

At the appropriate elevation as shown in the construction drawing, the first layer of geogrid is installed. The geogrid is placed from the front of the modular block extending to the back of the reinforced zone. It is important that the principal strength or machine direction of the geogrid is placed perpendicular to the wall alignment. The geogrid is pulled taut and kept in that way with stakes as shown in Figure 8. Subsequent courses of blocks, backfill and geogrid are installed as described earlier until the wall erection is completed. During the construction of the wall before its completion, the construction was temporarily halted due to festive holiday season. During this period of inactivity, there was continuous heavy downpour of monsoon rain over several days. As a result, a stream of gushing water rushing down the slope impact directly onto the unfinished wall. The backfill material was washed away and several top layers of unreinforced blocks were also washed away. Remedial solution was immediately implemented to overcome the problem and prevent future occurrence. Temporary drainage channel were provided and secondary geogrid reinforcement were installed. The wall was completed in April 1999 without further incidence. Figure 9 is a picture of the completed wall. Todate, it is found to perform satisfactorily.

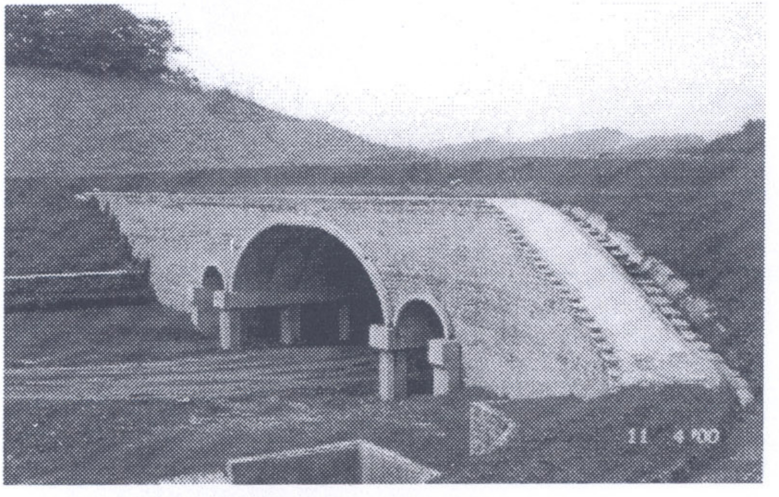

Figure 9: Picture of completed segmental wall

CONCLUSION

A 9.6 m high segmental wall was designed and constructed with geogrid made of high tenacity polyester yarn knitted to form a network of apertures. The facing is constructed of hollow cored modular precast concrete blocks dry stacked together. The hollow cores are infilled with aggregates to enhance positive interlock between the blocks, increase the weight of each unit and maintain the porosity of the facing. Well compacted granular material was used as backfill. The completed wall is performing satisfactorily.

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