Mechanically Stabilized Backfill, Wu (ed.) © 1997 Balkema, Rotterdam, ISBN 90 5410 902 5

Design, construction and performance of an anchored earth wall in Malaysia

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ABSTRACT : Anchored Earth is a type of mechanically stabilized backfill structure where the mode of stress transfer from the backfill to the reinforcement is by passive resistance in addition to friction. This paper summarises the historical development of Anchored Earth, describes the embodiment of the local system and highlights a case history involving the construction of a flyover over a busy rairoad where by Anchored Earth was used as bridge abutments and embankment wall. The maximum height of the wall reaches as high as 13.0m.

1 HISTORICAL DEVELOPMENT

Anchored Earth is a type of mechanically stabilized backfill structure where the mode of stress trancsfer from the backfill to the reinforcement is by passive resistance in addition to friction. One of the earliest version of Anchored Earth was invented by Andre Coyne in 1929. A schematic representation of the invention called Ladder Wall is shown in Fig. 1. The first structure that was built using the system was a 4.5 m high quaywall constructed in Brest, France in 1928. The use of Ladder Wall was discontinued after World War II. After a long lapse of silence, the Transport and Road Research Laboratory in UK came up with their version of Anchored Earth in 1981. A schematic representation of the system is shown in Fig. 2 and the application of such system was first reported in 1985. (Jones, et al 1985) The anchors used by TRRL are either triangular loops or the turpentine 'Z' type. Parallel development of Anchored Earth took place in other parts of the world including Japan and USA.

2 THE ANCHORED EARTH SYSTEM

The schematic representation of the Malaysian embodiment of the AE system is shown in Fig. 3. The system consists of three major components namely the facing panel, the reinforcing tendons and the anchor blocks.

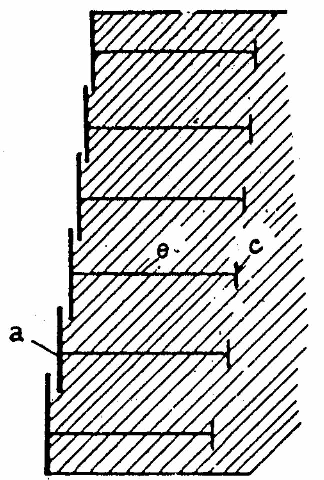

Fig. 1 Coyne's Ladder Wall Patented in 1929

2.1 Facing Panels

The facing panels are hexagonal shaped and are made of precast concrete (grade 30) as shown in Fig. 4. They are interlocked with dowels bars with tolerance for horizontal movements. The horizontal joints between the panels are inserted with compressible material to allow for vertical movement. As such the facing is flexible and can tolerate large differential settlement.

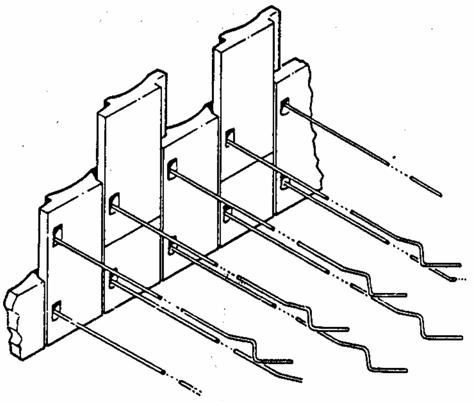

Fig. 2 Schematic Representation of TRRL Anchored Earth System

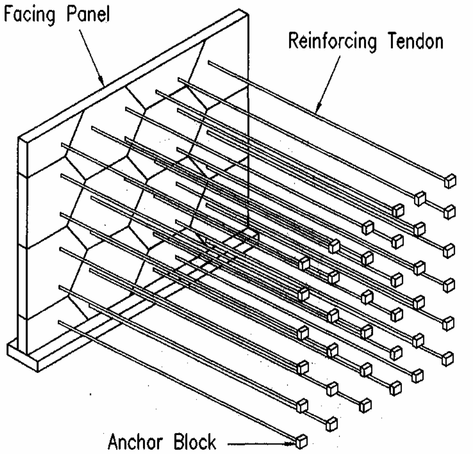

Fig. 3 Schematic Representation of Nehemiah Anchored Earth Wall System

2.2 Reinforcing Tendons

The reinforcing tendons are made of carbon steel rods in compliance with BS 8006:1994 Code of practice for Strengthened/reinforced soils and other fills. The tendons are hot-dipped galvanised to prevent corrosion. The advantage of using round bars instead of strips is that it is more durable against corrosion in view of the reduced surface area exposed. The tendons are connected to the facing panels by nuts with the threaded end coated with epoxy.

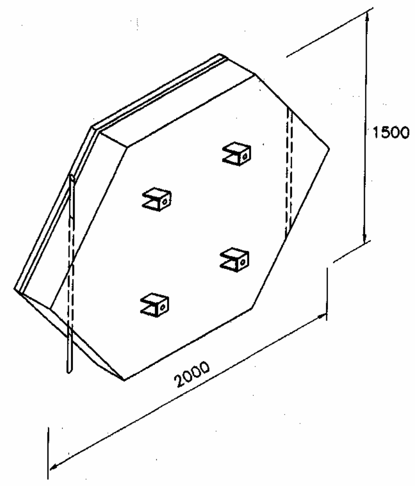

Fig. 4 Hexagonal Shaped Facing Panel of AE Wall

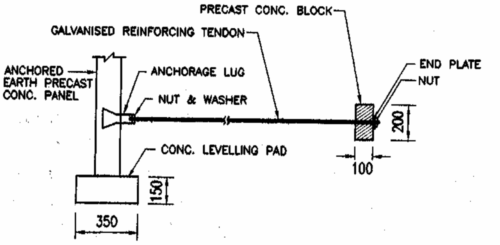

Fig. 5 Typical Arrangement of Facing Panel, Reinforcing Tendons and Anchor Block

2.3 Anchor blocks

The anchor blocks are discrete precast concrete blocks which act as deadmen. A hole is preformed in the centre of the block to enable the tendon to pass through thereby connected with nut and washer. A typical arrangement is shown in Fig. 5. The advantage of using anchor blocks is that it enhance the pull out resistance of the reinforcing tendon. As a result, the use of cohesive frictional material as backfill is possible since the system does not rely so much on friction for the stress transfer.

3 CASE HISTORY

This case history involved the construction of a flyover over a busy railroad at Pantai Dalam, Kuala Lumpur. Originally, the road crossed over the railway at grade. However, with the electrification

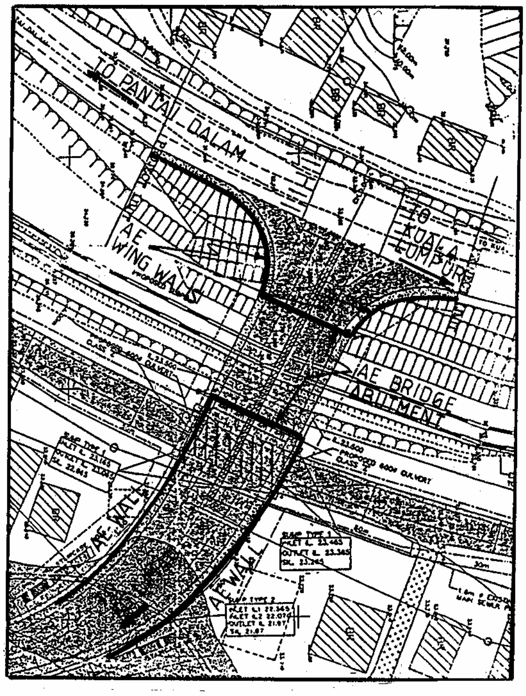

Fig. 6 Layout Of AE Wall Alignment

of the railway and the construction of an additional railway track, the construction of the flyover become imperative. The alignment of the Anchored Earth wall is shown in the layout plan in Fig. 6.

3.1 Design

The subsoil condition of the project site is shown in the borehole logs in Fig. 7. In general, up to 4 m of top soil consisting of firm silty clay or loose silty sands was found to overly hard material (Toh, 1994). As such, the top soil was removed and replaced with well compacted granular material. The typical section of the embankment wall and bridge abutment is shown in Fig. 8 and 9 respectively.

3.1.1 External stability

For the external stability analysis, the AE wall is analysed to act as a gravity block. The factors of safety against sliding, bearing and overturning of the block were checked and designed to ensure that they are adequate. (see Fig 10)

3.1.2 Internal stability

As for the internal stability analysis, the tie back wedge method as described in BS 8006: 1994 was adopted. The design is to ensure that there is adequate factor of safety against tensile and pull-out failure of the reinforcing tendons.

3.1.2.1 Tensile failure

The tensions in the reinforcing tendons are computed as follows:

$$T_i = K \ S_v \ \sigma_v$$

where,

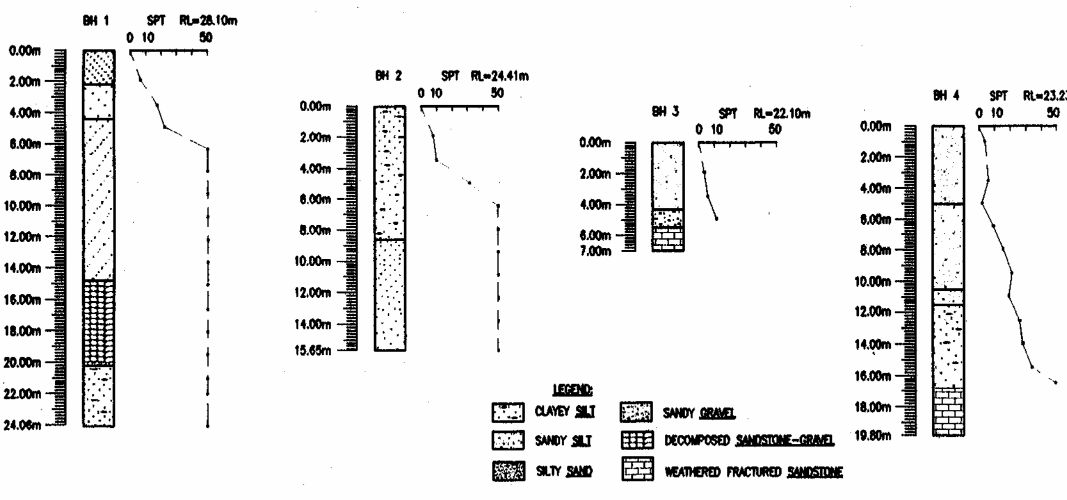

Fig. 7. Subsoil Condition at Site

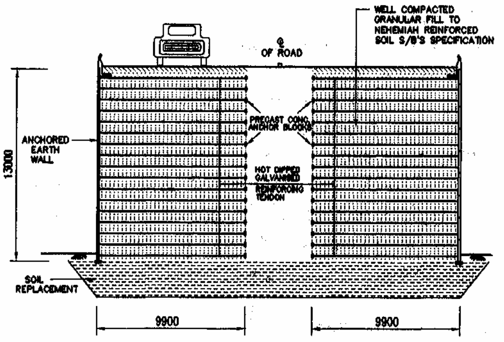

Fig. 8 Typical Section of AE Embankment Wall

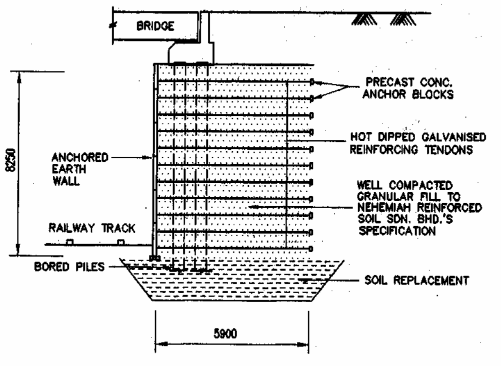

Fig. 9 Typical Section of AE Bridge Abutment

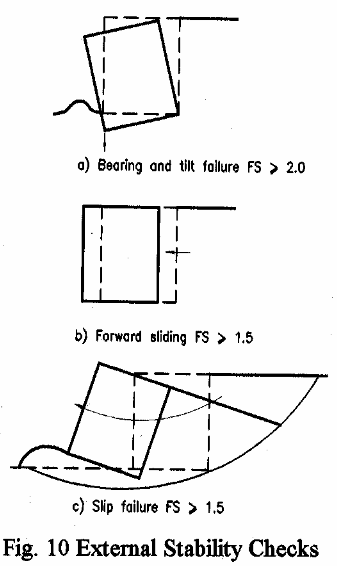

Fig. 10 External Stability Checks

T_i is tension in the reinforcing tendon, at ith level

K is the coefficient of earth pressure within the reinforced volume,

S_v is the vertical spacing of the tendons

σ_v is the vertical stress acting on the ith level of tendon according to the Meyerhof distribution.

It is to be noted that to be on the conservative side and in order to take into consideration of the locked in stresses due to the compactive effort, the coefficient of earth pressure is taken to be Ko at the top of the wall reducing linearly with depth to a value of Ka at a depth of 6 meters below the top of the structure,

where,

Ko is the coefficient of earth pressure at rest and,

Ka is the coefficient active earth pressure.

3.1.2.2 Pull-out failure

The ultimate pull-out resistance of the reinforcing tendons is the sum of the shaft resistance and the anchor capacity of the anchor block. The shaft resistance is determined by the friction developed between the backfill and the effective length of the tendon which is shown in Fig. 11. The anchor capacity is compluted as folows:

$$Pa = 4K_p\, h\, w\, \sigma_v$$

where,

Pa is the passive resistance of the soil in front of the anchor block

σ_v is the vertical stress at the particular tendon level

K_p is the coefficient of passive earth pressure

h is the height of the anchor block

w is the width of the anchor block

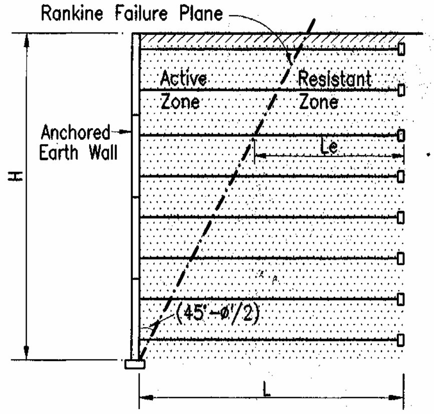

Fig. 11 Effective Length of Reinforcing Tendons - Le

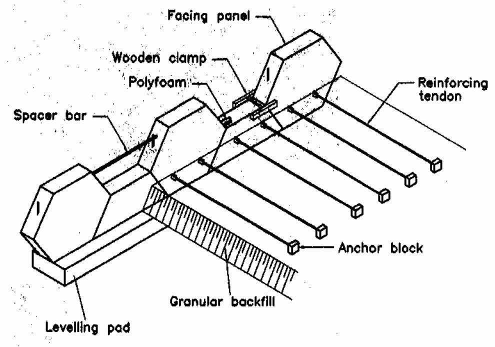

Fig. 12 Construction of AE Wall

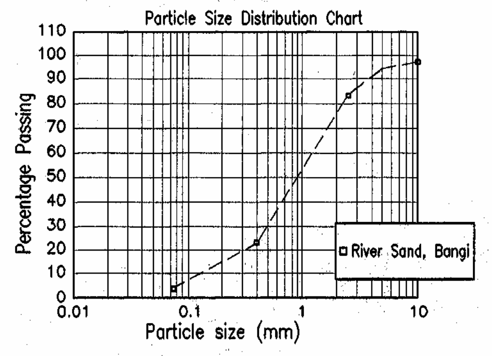

Fig. 13 Particle Size Distribution of Bangi River Sand

3.2 Construction

The first step in the construction is to remove the unsuitable subsoil material and replaced with well compacted granular material.

Once the subsoil is strengthened, the levelling pad is casted at the formation level. (see Fig. 12) The first course of facing panels are placed on the levelling pad. The panels are supported with temporary props and wooden clamps. The granular material is then backfilled, spread, levelled and compacted to the first tendon level. The reinforcing tendons are then connected to the facing panels and the anchor blocks. This process of installing panels, backfill, tendons and anchor blocks is repeated until the full height of the wall is reached. The maximum height of the wall is 13.0 m. The thickness of each lift of backfill is 375 mm.

River sand from Bangi was used as backfill. The typical grain size distribution is as shown in Fig. 13. The pH value is 6.9. These mechanical and electrochemical properties are well within the requirements of the specification. As such the river sand was approved as suitable backfill material.

Erection was rapid and easy and a rate of 800 m2 of wall area per month was achieved when the supply of backfill was consistent. The main constrain to the speed of erection is the supply of backfill. When the supply is uninterupted an erection rate of 2000 m2 per team per month is achievable. The wall was completed in September 1995. (see Plate I and II)

3.3 Performance

The performance of the AE wall was monitored by instrumentation and testings. The instrumented section is as shown in Fig. 14. Twenty one resistance wire strain gauges were installed to measure the stresses developed in the tendons. Unfortunately, the reading were erractic and not realiable. The lateral movement was monitored by means of an inclinometer. The results are shown in Fig. 15. It is seen that the maximum lateral movement is less than 6 mm. A vibrating wire

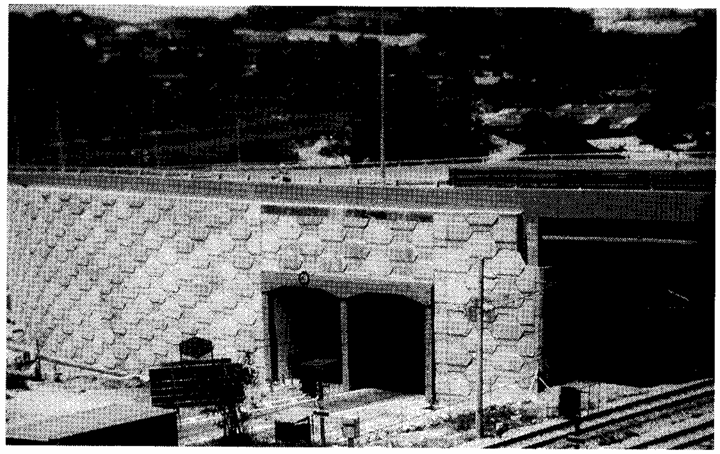

Plate I: Anchored Earth Embankment Wall

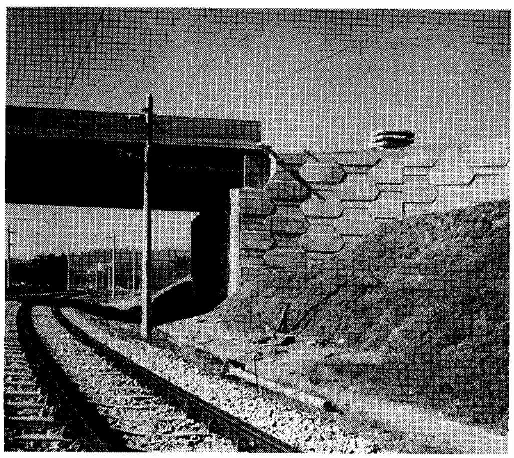

Plate II: Anchored Earth Bridge Abutment

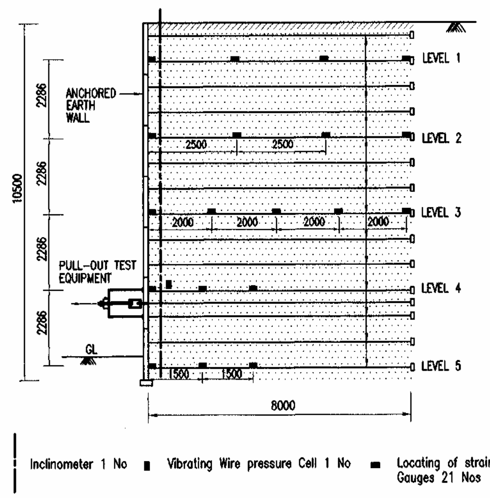

Fig. 14 Instrumented Section of AE Wall

total pressure cell was installed at the backface of the facing panel to measure the horizontal pressure exerted on the wall facing as the overburden increases. The results is shown in Fig. 16. It is seen that the the measured lateral soil pressure at the back face of the facing panel is well below the Ka line. Field pull out test as shown in Fig. 14 was carried out to measure the apparent pull out resistance of the anchor reinforcing tendons. As can be seen from the results shown in Fig. 17 the pull out resistance of 79 KN is about three times the working load of 26 KN in the tendon. The pull out resistance well exceeded the required

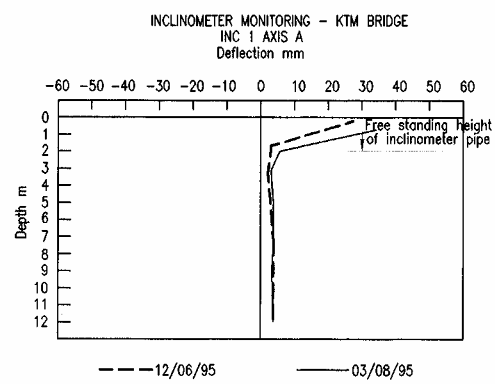

Fig. 15 Lateral Movement of AE wall

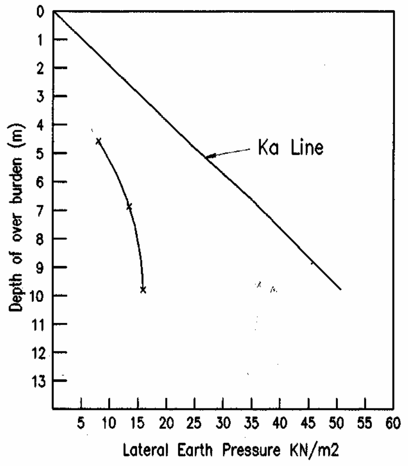

Fig.16 Relation Between Depth of Fill and the Horizontal Pressure on the Facing

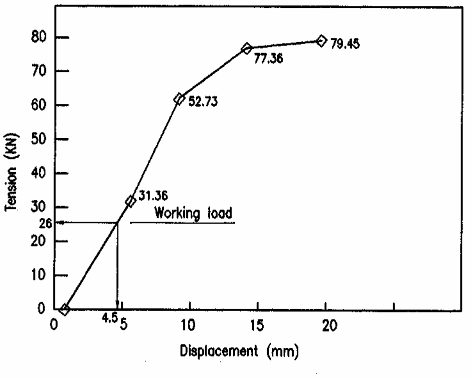

Fig.17 Pull Out Test Results

factor of safety of 2.00. Todate the wall is found to be sound and performing satisfactorily.

CONCLUSION

A 13.0 m high Anchored Earth wall was designed and constructed in Malaysia according to established sound engineering practice and found to be performing satisfactorily.

REFERENCE

BS8006 : 1994 Code Of Practice For Strengthered / Reinforced Soils and Other Fills.

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