The Case Record of Ba-Yu-Quan Anchor Slab Retaining Wall

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SYNOPSIS: Anchor slab retaining wall is a kind of retaining structure, which consists of prefabricated rib-columns, panel slabs, tie-bars and anchor slabs embedded in earth fill. Since the structure was first used and developed in China in 1974, many such structure have been built on railways and other engineering projects. The reviewer of Second International Conference on Case Histories in Geotechnical Engineering gave a comments about this structure as follows: "Chinese method anchor slab the construction should interest the western world".

Ba-Yu-Quan anchor slab retaining wall has been instrumented to measure the load on the tie-bar, the horizontal displacement of the rib-columns, the horizontal earth pressure acting at the panel slabs, and the backfill settlement at different positions. This paper presents project description, construction of the project, data obtained from field observations and the comparison result with analysis and predicted values.

INTRODUCTION

Ba-Yu-Quan anchor slab retaining wall was constructed in the year of 1984-86. It is located in Ba-Yu-Quan harbour, Liaoning province. The wall was constructed for the purpose of retaining the fill at two sections of a railway, each section is a 100 m anchor slab wall, which approaches to an overhead street bridge, as shown in Fig. 1 and Fig. 2, so as to save a great quantity of cropland that is very expensive at the place in question.

Fig. 1. The Whole Scene of Ba-Yu-Quan Anchor Slab Retaining Wall

The anchor slab retaining wall maintains it-self stabilization through the interaction of face panel, rib-column, tie-bar, anchor slab and backfill, in other words anchor slab structure is an assembled retaining structure.

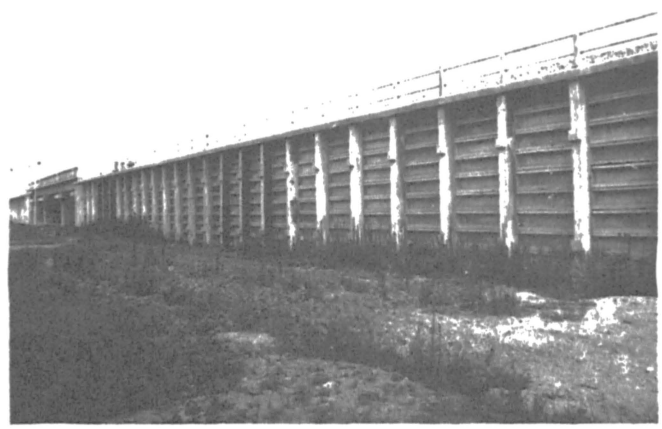

Fig. 2. Photograph of Ba-Yu-Quan Anchor Slab Retaining Wall

As compared with reinforced earth structure, this new type structure is better for protection against corrosion, while it has the advantages of light weight and lower cost. It is suitable to be adopted in regions of low bearing capacity and especially promising in those countries, where reinforcing steel straps is in short supply.

A vibrostand model test has provided information for anchor slab structure that is comparatively flexible and better to against the damage of earthquake than masonry retaining walls.

PROJECT DESCRIPTION

The face panel of Ba-Yu-Quan anchor slab wall consists of reinforcement concrete rib-column and panel slab. The rib-column is 5 m in hight and with 45x25 cm rectangular section. Specing of rib-column is 2 m from center-to-center.

The panel slab is a trough plate 1.96 m in length, 0.5 m in width and 20 cm in thickness.

The foundation of rib-column is a strap concrete footing, 0.8 m in width, 1.25 m in depth, the bottom of foundation is 0.25 m bellow frost depth.

A 65x25 cm job-placed armoured concrete cross beam is placed at the top of rib-column holding it in place.

One rib-column is anchored by two pieces of 1.2 m square anchor slab with 0.25 m in thickness embedded in the earthfill. The rib-column and anchor slab are joined up with 2xϕ28 mm bar stock. The upper tie-bar is 8 m and the lower one is 7 m in length, the cross section of Ba-Yu-Quan anchor slab wall is shown in Fig. 3.

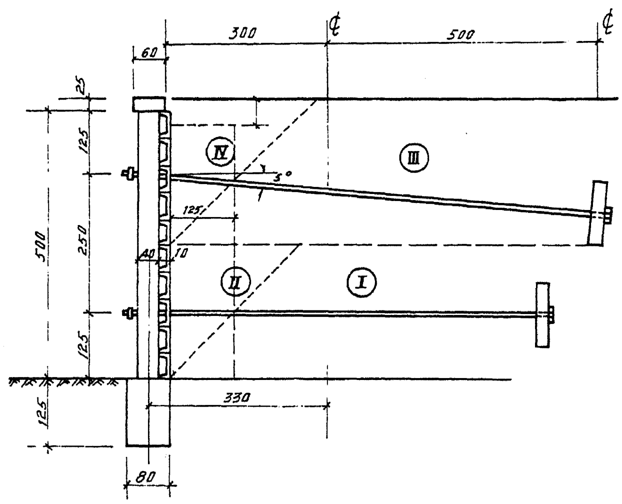

Fig. 3. The Section of Ba-Yu-Quan Anchor Slab Retaining Wall

In design the soil parameters are given as follows,

Unit weight of backfill γ =1.90 kN/m^3;

Angle of internal friction ϕ =30°;

Angle of wall friction δ =0.5ϕ;

Bearing capacity of subsoil R=120kPa.

Rib-column, panel slab, tie-bar and anchor slab are designed according to lateral pressure acting on panel slab, which consists of Coulomb's active earth pressure and additional lateral pressure caused by external concentrated load. (Casagrande. L., 1973) Both lateral pressure mentioned above were multiplied by a experimental coefficient of 1.2.

The allowable carrying capacity of anchor slab embedded in backfill was chosen as 100-150 kN/m^2 (Lu, Z.J. et.al 1985) at different depth respectively.

The length of tie-bars is designed to extend no less than a distance of 3.5 B beyond the imaginary line of rupture of active earth pressure, in which B denotes the length of one side of the needs of partial and whole stability analysis of anchor slab wall.

CONSTRUCTION

Due to Ba-Yu-Quan anchor slab wall is located in a frigid region, a pervious blanket of 1.25 m in thickness was placed at the back of face panel to protect the wall from frost heave.

The tie-bar were protected against corrosion by coating two layers of rust-resisting paint and winded two layers of spun glass cloth round the bar stock and coated with melted pitch at the same time.

According to the authors' experience, in order to reduce the displacement of an anchor slab wall, the backfill should be compacted and the foundation must not be very soft. The backfill was constructed by a total of 4 stages, which is approximately in order of (I)-(IV) marked in Fig. 3. Each layer of earth fill should not be more than 30 cm and compacted to 95% of optimum density.

After the surface of fill reached to the top level of anchor slab, a ditch cut was excavated in backfill to put the tie-bar and anchor slab in place. Plain concrete was concreted in front gap between the anchor slab and ditch wall, then earthfill was placed in the back gap and compacted to the stipulate density.

A temporary wooden support was used to hold the rib-column in right place, after filling the whole backfill, then concreting the cross beam, welding the banisters and stuffing the tie-bar ends with cement morter so as to protect against corrosion.

FIELD INSTRUMENTATION

The instrumented areas were chosen in the rib-columns No. 21-22 and No. 23-24. Both sections between the above columns was sufficiently distant from bridge to make the analyses of data easier.

Totally 30 vibrating wire transducers were installed on above sections, along the rib-column to measure total horizontal earth pressure and its distribution.

On each of the instrumented panel slabs, 3 transducers were mounted between the rib-column and the panel slab, so as to form a state with three sustainers.

16 bar-stock tensiometers were welded on the end of the tie-bar of four rib-columns, located at instrumented area, to measure total tensile force,

To monitor the lateral displacement of the face panel of the wall, on each of rib-columns top and bottom was mounted a mark, in the meantime a reference line for displacement measurement has been established when the rib-column was stood up and the face of backfill reached to the height of half panel slab.

A cup type settlement gauges were also embedded on the anchor slab top to measure its settlement in the backfill.

Field measurement have been made during and after construction and will be measured once or twice each year in the near future.

COMPARISON BETWEEN PREDICTED AND MEASURED VALUES

To examine the predicted value with the field measurement data was the important aim of the field measurement. The tensile force of tie-bar and earth pressure of face panel field measurement data of instrumentation section 1, which is between the rib-column No. 23-24, and its predicted values are shown in Table 1 and Fig. 4.

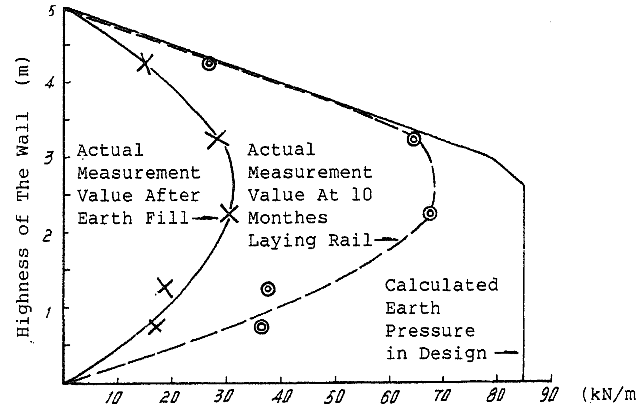

Fig. 4. The Earth Pressure Distribution of Observation Section

TABLE 1. The Predicted and Measured Tie-Bar Force and Observed Earth Pressure

Location	Design Force (kN)			Measurement Tie-Bar Force (kN)		Measurement Earth Pressure (kN)	
	Backfill Weight Only	Include Track Load	Include External Load	After Earth Fill	10 monthes After Laying Rail	After Earth Fill	10 monthes After Laying Rail
The Upper Tie-Bar	66.7	74.0	88.5	48.7	107.6	99.2	212.5
The Lower Tie-Bar	106.5	140.3	202.2	29.0	102.5		
Column Bottom	10.0	12.8	19.1	21.5*	2.4*		
Total	183.2	227.1	309.8	77.7	210.1		

It can be seen from Table 1 that just at the time after backfill was completed, both observation tie-bar tensile force of 77.7 kN and earth pressure of 99.2 kN are about less than a half of the predicted force of 183.2 kN. But 10 monthes after laying rail not only observation tie-bar tensile force of 210.1 kN is about the same, as the earth pressure of 212.5 kN, but also both the above force are the same with design tie-bar force of 227.1 kN, so it can be proved that the earth pressure graph which was shown in Fig. 4 and its quantity adopted in design are conform to the actual situation on the whole.

As compared the actual measurement tie-bar tensile force and earth pressure as mentioned above with total design force, which including the train external load of 309.8 kN, that the former is two-thirds about the latter. It can be borne out that the anchor slab, tie-bar, rib-column and panel slab are all in a state of safety enough.

The authors have measured the tie-bar force at some other anchor slab projects during the train was just parked on the top of earthfill of retaining wall. As a result the tie-bar force had a extreme little increment than the force without the train load. In addition the first author, Z. S. Zhang, had performed finite element analysis on some of the anchor slab structures including the one mentioned above (Zhang, Z.S. 1985). The results of finite element analysis has shown the same phenomenon mentioned above.

The values with mark * in Table 1. is the calculative values according to the measurement of earth pressure and total tie-bar force, that is to deduct the actual measurement tie-bar force from the actual total measurement earth pressure shold be the force supported by the column bottom, there's hardly any difference between the two.

It can be proved that put a column into a shallow nest on foundation, the column bottom could not be formed as a strong support.

The maximum settlement of anchor slab embedded in backfill was 38 mm. It is agreed with the result obtained from finite element analysis.

The actual observation data of horizontal displacement of face panel is shown in Fig. 5.

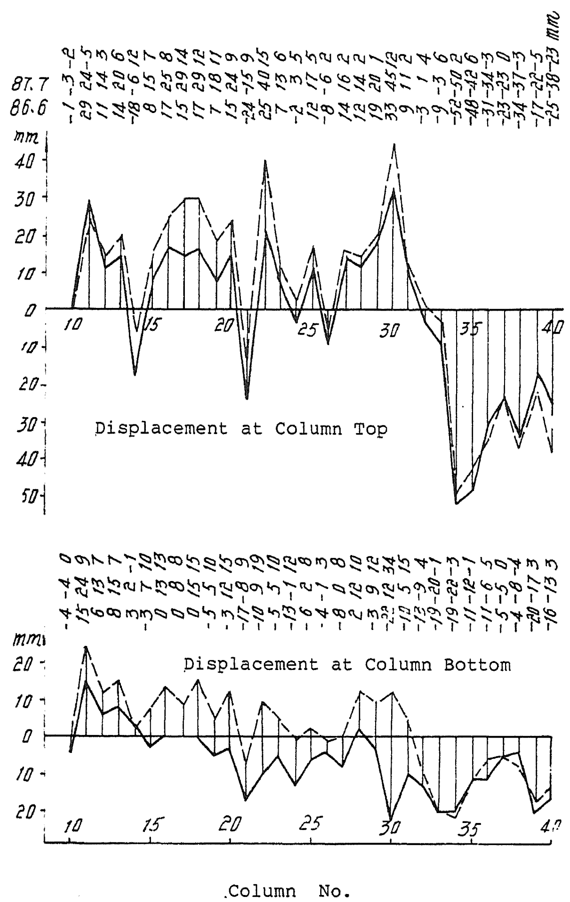

Fig. 5. The Horizontal Displacement Observation Data of Face Panel

When the backfill was just completed, the maximum horizontal displacement of the face panel is 52 mm arised at the top of No. 34 column which is near the end of the wall. It has good reason to say, that this displacement was mainly forming by the hoisting and assembling deviation of the column.

The average horizontal deviation at column top is 18.03 mm and the average horizontal deviation at column bottom is 8.55 mm. Due to the top assembling deviation is only 10 mm greater than that of bottom, therefore the appearance of the face panel of the wall is remain the same smooth.

The last actual displacement observation is 10 monthes after laying rail, which is shown in Fig. 5. The average displacement at top is 6.5 mm and the average displacement at bottom is 8.4 mm. It can be deemed that the column is belong to a small parallel move. This phenomenon and displacement values are quite close to the finite element analysis result.

CONCLUSIONS

The investigations described in this paper have shown:

Anchor slab retaining wall is a kind of assembled retaining structure, it has the advantages of light weight, lower cost and better for protection against corrosion.

In order to reduce the displacement of an anchor slab wall, besides the backfill should be compacted and the foundation must not be very soft, it has to be made the each other gaps between rib-column, panel slab, tie-bar, anchor slab and backfill as close as possible during the wall assembled period.

The dimension of anchor slab must be calculated according to the allowable carrying capacity of anchor slab embedded in backfill, the actual situation of the project makes clear that the value of 100-150 kN/m² used in design with ampth factor of safety.

As compared the actual measurement tie-bar force and earth pressure were observed in the project, that can be concluded the column bottom could not be formed as a strong support.

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