Construction and Performance of Spillway Walls for Mukakuning Dam

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ABSTRACT: The fabric reinforced Spillway Walls of the Mukakuning Dam have been in service since 1988. The backfill materials are residual soils. The maximum height of the walls was 10.8 m with nineteen layers of geofabrics with an ultimate tensile strength of 200 kN/m. The maximum settlement of the top of the walls was about 200 mm and the maximum total horizontal displacement of the walls was about 280 mm.

1 INTRODUCTION

The Spillway Walls of the Mukakuning Dam, at Batam Island, Indonesia were originally designed as conventional reinforced concrete walls. Fabric reinforced walls were introduced as an alternative to the concrete walls. This paper discusses the design, construction and performance of the fabric reinforced walls.

2 SPILLWAY WALLS

Figure 1 shows the section of three different parts of the spillway. Walls with a height of more than 6 meters were originally designed as concrete gravity walls, while walls with a height of less than 6 meters were designed as concrete cantilever walls. The apron and the stilling basins were designed as gravity walls while the chute wall was designed as cantilever walls. Fabric reinforced walls were introduced as an alternative to the concrete walls.

3 PROPERTIES OF SOIL BACKFILL

A soil investigation was carried out to obtain index properties such as soil classification, Atterberg limits, gradation, and compaction test results, and shear strengths. In situ compaction tests were done in order to select the field compaction machinery needed. The test results were reported by Djawardi (1988).

Soils with low plasticity (CL according to the Unified Soil Classification System) were then selected as backfill material. The properties of the backfill soils used in the design of the walls are:

Maximum dry density: 18 kN/m^3 (from Modified Proctor)
Optimum moisture content: 18 %
Cohesion: 16 kN/m^2
Internal angle of friction: 15 degrees
Percent compaction required: 95

From the results of field trial compaction tests, the number of passes to achieve the maximum dry density was eight.

The backfill soils were mainly residual soils derived from the weathering of the silty sandstone, siltstone, and shale of the Central Batam Formation.

4 FABRIC REINFORCED WALL DESIGN

The service life of the Spillway as required in the specifications is 50 years.

A polyester woven fabric (Stabilenka 200/45) was selected as the fabric reinforcement in the Spillway walls. The ultimate tensile strength of the fabric was 200 kN/m. The working load on the fabric was designed at 25% of the ultimate tensile strength (50 kN/m). At this allowable load, there is believed to be a sufficient protection against factors such as potential degradation of the fabric due to environment changes and creep characteristic of the fabric over its service life of 50 years.

The purpose of the redesign of the walls was to reduce the concrete volume required. By reinforcing the backfill soils with geofabrics, the concrete wall thickness was reduced to the minimum. This was made possible because the concrete walls were designed as free standing walls with zero soil pressures acting on them. Typical sections of the redesigned walls are shown in Fig 1. The fabric reinforced wall was built 1.0 m behind each concrete wall. The top of the space between the concrete and fabric wall was covered. The purpose of the space between concrete and fabric reinforced walls was to accommodate the displacement of the fabric reinforced walls during their service life.

For the 10.8 m high chute walls, the number of fabric layers used was 19, and the fabric length was 12 m. The computed factor of safety for internal stability based on the two wedge limit equilibrium method was 1.3, and the computed factor of safety for overall external stability involving circular slip surfaces based on Modified Bishop method (Bishop 1955) was 1.5.

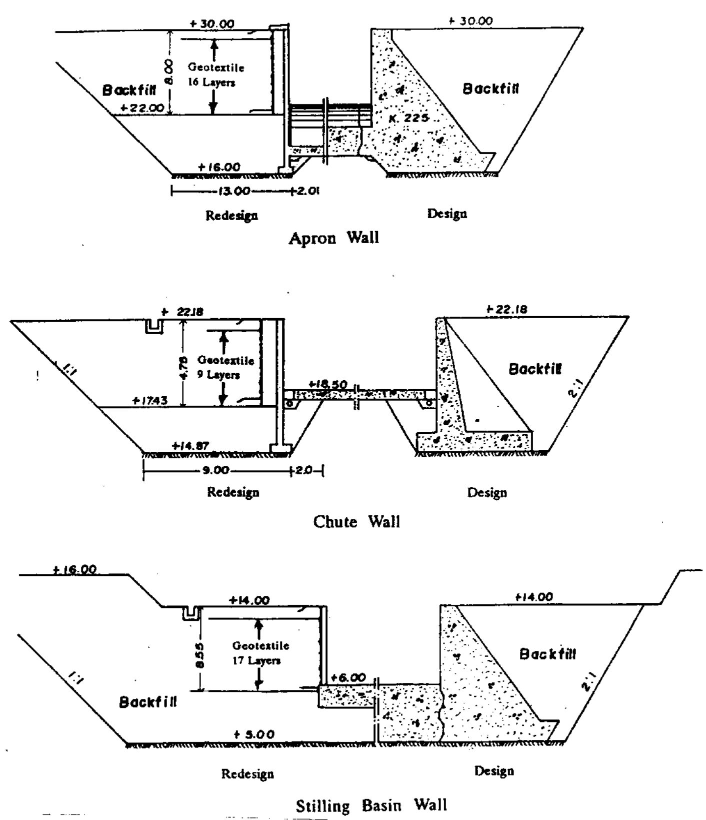

Fig. 1 - Cross sections of original and redesigned walls

5 CONSTRUCTION

Since the fabric reinforced walls to be constructed were relatively high, and a concrete walls in front of each reinforced wall had already been completed when construction of reinforced walls started, the use of formwork to form a vertical face of the wall would have given a problem during their installation and subsequent removal due to the limited space available. To solve this problem, a sand bag wall was introduced to form the vertical wall face as shown in Fig. 2.

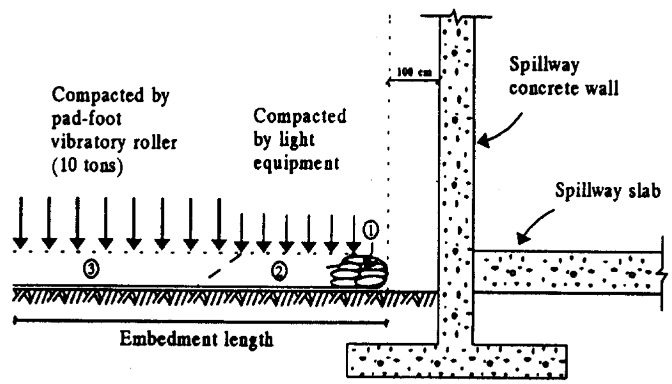

Fig. 2 - Construction of fabric reinforced walls

The sequence of the fabric reinforced wall construction was:

a) Placing sand bags to form a vertical starter wall for each lift.
b) Placing an initial backfill adjacent to the wall facing and compacting by a light compactor (with static weight of 3 tonnes) at a 250 mm lift thickness. Compaction values averaged 85% of the maximum dry density of the Modified Proctor Compaction Test. The lift thickness of 250 mm was adopted based on the result of the trial fill tests. The spacings between the fabric layers used in deign and construction of the walls were multiples of 250 mm, such as 500 mm, 750 mm and 1000 mm.
c) Upon the completion of compaction on the initial backfill, the completion of the placement of the layers were then carried out and compacted by a vibratory padfoot roller. The number of passes was 8 passes according to the field compaction trial to achieve at least 95% of the maximum dry density of the Modified Proctor Compaction Test.

The above procedure was repeated until the tops of the fabric reinforced walls reached their final levels. The horizontal deformations of the walls during construction were monitored.

The total costs of the fabric reinforced walls as constructed were about 40 percent of the estimated costs of the originally designed reinforced concrete walls.

6 MONITORING

The monitoring of the displacements of the fabric reinforced walls was initiated just after the completion of the walls. The measured horizontal and settlements are shown in Fig. 3 and Fig. 4 respectively. The rates of displacement were largest in the first 3 months of monitoring and became progressively smaller with time. Two years after the completion of construction, the movements had essentially ceased.

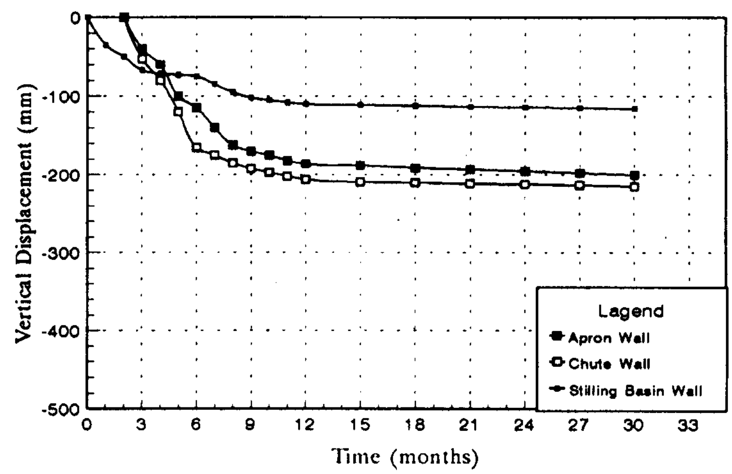

Fig. 4 - Measured settlements of top of walls

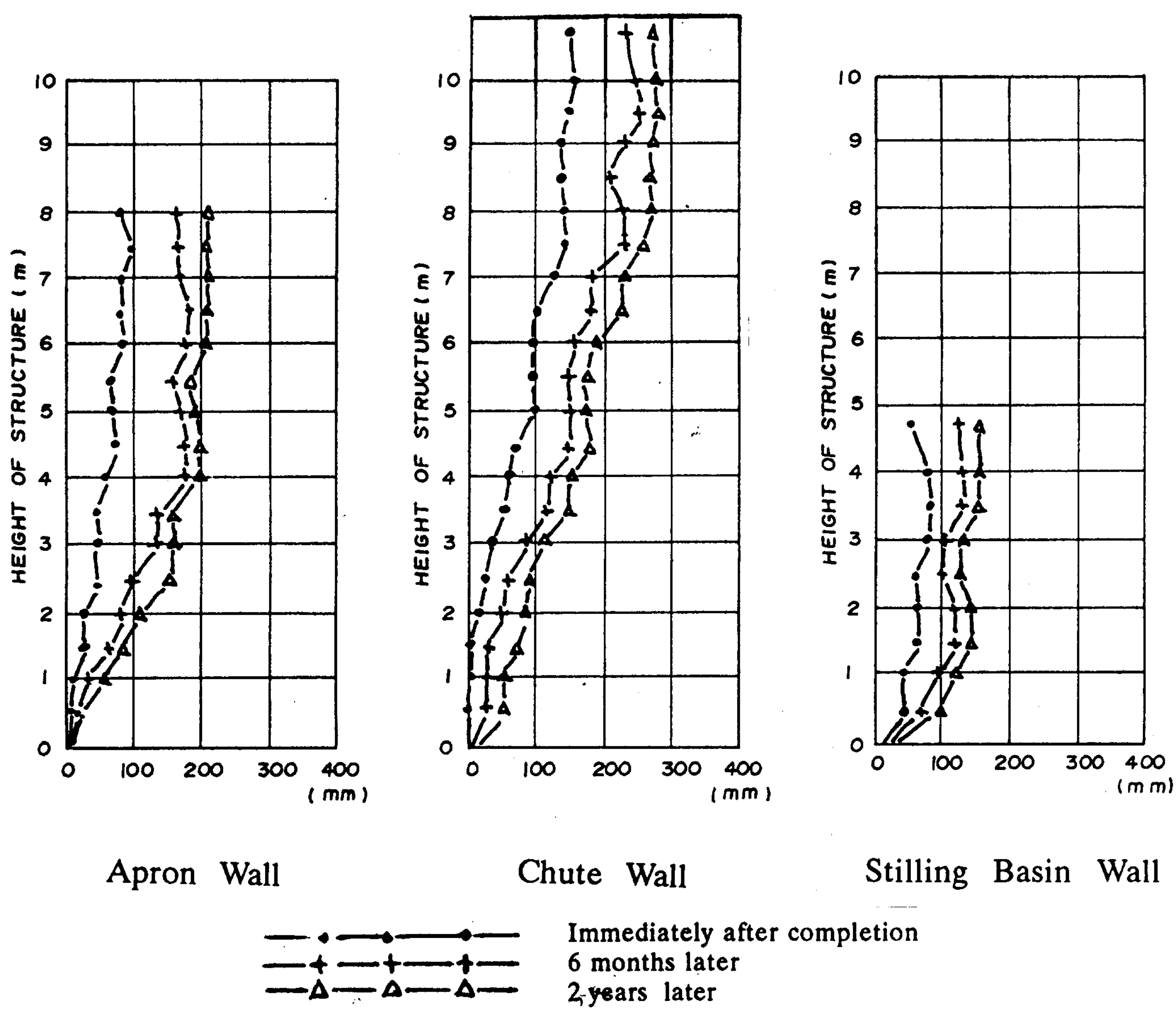

Fig. 3 - Measured horizontal displacements of walls

After the completion of the construction of the fabric reinforced walls, a cover was placed over the top of the of space between the concrete and the fabric reinforced. Monitoring chambers were placed in 14 locations along the walls in order to monitor the deformations of the walls. The monitoring was done by weekly in the first 3 month, fortnightly in the next 3 months, and then monthly over the next 18 months after completion of the walls. After 2 years, the monitoring is being done intermittently.
The horizontal deformations were measured at vertical interval of 0.50 m, by measuring the distance from the fabric reinforced wall face to the face of the concrete walls. The vertical deformations of the top of the fabric reinforced walls were measured by conventional leveling against permanent reference points.

7 CONCLUSIONS

The Spillway Walls of the Mukakuning Dam have been in service since 1988. The backfill materials are residual soils. The maximum height of the walls was 10.8 m with nineteen layers of geofabrics with an ultimate tensile strength of 200 kN/m. The maximum settlement of the top of the walls was about 200 mm and the maximum total horizontal displacement of the walls was about 280 mm. The displacements had essentially ceased two years after the completion of the walls. The performances the fabric reinforced walls have been thus very satisfactory. The fabric reinforced walls were substantially less expensive to build than the originally designed reinforced concrete walls.

REFERENCES

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