Chapter 4

SURCHARGE LOADING SYSTEM

To apply a strip surcharge loading at the surface of the backfill, a surcharge loading system was developed for the non-yielding retaining-wall facility of NCTU. The loading system consists of the following four parts: (1) reaction frame; (2) vertical-force loading system; (3) strip footing; and (4) settlement measuring system. The details of the surcharge loading system are introduced in the following sections.

4.1 Reaction Frame

To provide adequate reaction for the mechanical actuator, a reaction frame was constructed around the soil bin, as shown in Fig. 4.1. It should be emphasized that the reaction frame was fixed to the strong floor and was independent of soil bin and model wall. The reaction frame consists of four parts: (1) columns; (2) fixed beams; (3) movable beam; and (4) lateral bracing, as indicated in Fig. 4.2. All of the columns and beams are made of I-section steel beams (Designation: W 6 $\times$20). The moment of inertia of the cross-section of the beam is 1.72×10^{-5} m^4. The columns are 2.5 m-high and fixed to 1 m-thick reinforced-concrete floor by penetrating of four threaded bolts that was cemented to the strong floor with epoxy resin. Two 2.6 m-long fixed beams were connected to four fixed columns with steel bolts. On the flange of each fixed beams, 24 pairs of holes (diameter = 10 mm) were drilled 100 mm apart. The holes are used to connect the movable beam and the fixed beams. Fig. 4.1 shows the mechanical actuator is attached to the movable beam with two steel plates and four steel bolts. With this reaction frame design, the mechanical actuator could move freely in the horizontal x-y plane. To ensure stability of the reaction frame, a lateral bracing was added as shown in Fig. 4.1. The lateral bracing was made of steel angles (Designation: L 13/8 ×13/8 ×1/4).

4.2 Surcharge Loading System

To apply a surcharge load on the surface of the backfill, a vertical-force loading system including (1) mechanical actuator; (2) control panel; and (3) load cell was established, as shown in Fig.4.3.

4.2.1 Mechanical Actuator

The mechanical actuator build for this study is shown in Fig.4.4. The maximum output force of the mechanical actuator is 2 ton. The 1/4 Hp motor in the actuator is made by LEESON (model C41D17FK2A). An electric motor and a gear box in the actuator supply the thrust to the loading ram. It should be mentioned that the actual force applied on the backfill should be observed with load cell. The maximum stroke of the actuator is 0.18 m.

4.2.2 Control Panel

The control panel shown in Fig. 4.5 was used to control the direction and speed of the loading ram attached to the actuator. The speed of the loading ram varies from 200mm/min to 0.05mm/min. For all experiments in this paper, the vertical loading is carefully controlled to keep surcharge loading a constant.

4.2.3 Load Cell

To measure the vertical loading transmitted to the footing accurately, a load cell (Kyowa LUK-A-5KNSA1, capacity = 5 kN) shown in Fig. 4.6 was used. The load cell was arranged at the end of the loading rod as indicated in Fig. 4.3. The measuring sensor should be placed as close as possible to the strip footing.

4.3 Strip Footing

To simulate the flexible and rigid surcharge loading conditions in the laboratory, two types strip footing were designed and constructed for this study as shown in Fig 4.7. The flexible footing shown in Fig. 4.7(a) should induce a uniform pressure on the backfill, and the rigid footing shown in Fig. 4.7(b) should induce a uniform settlement. The details of flexible and rigid footings for this study are discussed in the following sections.

4.3.1 Flexible Footing

In Fig. 4.8, the steel lid is 1.48 m-long, 0.13m-wide, and 0.05m-high. In Fig. 4.9, the air cushion is 1.45 m-long 0.1m-wide and 0.08m-high. The lid is made of a C-shape steel channel that is welded with two 15 mm-thick steel plates at two ends. The length of lid is selected to be 1.48 m so that the lid could be easily put in the 1.5m-wide soil bin. The air cushion shown in Fig. 4.9 is made of 1.5 mm-thick PVC flat piece and air is filled in with an air-pump. Terzaghi (1954) suggested that, to simulate an infinitely-long strip loading, the length of footing should at least 0.8H, where H is the height of the retaining wall. For this study, the length of flexible footing 1.45 m is obviously longer than 0.8 H (1.2 m) that suggested by Terzaghi.

To transmit the vertical force from the actuator, a steel socket with semi-spherical fillister was welded on the lid. The steel ball and socket are designed to ensure that only vertical force is carried over to the footing. The depth of the socket fillister is one third of the diameter of the steel ball (D = 30 mm) to ensure the function of the steel ball. To increase longitudinal stiffness of the lid, four reinforcing steel plates are welded on the top of the lid as shown in Fig. 4.10(a).

To measure the settlement of the footing under surcharge load, six removeable displacement transducer stands (50 mm × 50 mm) are attached to the lid with screws as indicated in Fig. 4.8(a).

4.3.2 Rigid Footing

The rigid footing as shown in Fig 4.8, 4.9, and 4.10(b) is 1.45 m-long 0.1m-wide and 0.045m-high. The footing plate is made with aluminum alloy to maintain the high stiffness of footing and to decrease the deadload of looting. To provide a uniform loading on the rigid footing, an air cushion is sandwiched between the steel lid and footing as shown in Fig. 4.10(b). It should be emphasized that all experiments were processed without the any air leakage, which might cause direct contact between the lid and footing. For measuring the settlement of rigid footing, two displacement transducers stand on the steel lid have to be removed, so that the displacement transducers could be set on the stands on the rigid footing as shown in Fig. 4.10(b).

4.4 Settlement Measuring System

To observe the settlement of the footing due to surcharge loading, a settlement measuring system is established. As indicated in Fig. 4.11, the settlement measuring system consists of a reference beam, steel connector, extension rod, and the displacement transducer (Kyowa DT-100A). The reference beam is made of a 2020 mm-long steel angle (Designation: L 2 ×2 ×5/16). Two ends of the reference beam were fixed on the walkway of the soil bin with C-shape clamps. It is obvious that the reference beam is independent of the surcharge loading system, and the settlement measurements are not influenced by the surcharge loading.

A steel connector is used to connect the steel rod to the reference beam. The reference beam can move on the walkway, the connector can slide on the reference beam, and the extension rod can move up and down. So the displacement transducer (Fig. 4.12) could move freely in x, y and z direction. It should be emphasized that the displacement transducer should be placed on the stand of the footing vertically with care as shown in Fig. 4.13.