Chapter 5

BACKFILL AND INTERFACE CHARACTISTICS

This chapter introduces the properties of the backfill and the interface characteristics between the backfill and the sidewall. Laboratory experiments have been conducted to investigate: (1) backfill properties; (2) distribution of soil density in the soil bin; and (3) sidewall friction.

5.1 Backfill Properties

Ottawa silica sand (ASTM C-778) was used for the model wall experiments. All tests were conducted under an air-dry condition. Physical properties of Ottawa sand are listed in Table 5.1. Grain-size distribution of the backfill is shown in Fig. 5.1.

Major factors considered in choosing the backfill material (Ottawa sand) are summarized as follows.

1. Its round shape, which avoids effect of angularity of soil grains.
2. Its uniform distribution of grain size (coefficient of uniformity $C_u = 1.52$), which avoids the effects due to soil gradation.
3. High rigidity of solid grains, which reduces possible disintegration of soil particles under loading.
4. Its high permeability, which allows fast drainage and therefore reduces water pressure behind the wall.

To establish the relationship between unit weight of backfill γ and its internal friction angle ϕ, direct shear tests have been conducted. The shear box used has a square (60 mm ×60 mm) cross-section, and its arrangement is shown in Fig. 5.2. Before shearing, Ottawa sand was air-pluviated into the shear box to the desired density. Details of the technique to control soil density are discussed in section 5.2.

Chang (2000) established the relationship between the internal friction angle ϕ and unit weight γ of Ottawa sand as shown in Fig. 5.3. It is obvious from the figure that soil strength increases with increasing soil density. For the air-pluviated backfill, an empirical relationship between soil unit weight γ and ϕ angle can be formulated as follows

$$\phi = 6.43\ \gamma - 68.99 \qquad (5.1)$$

where

ϕ = angle of internal friction of soil (degree)

γ = unit weight of soil (kN/m^3)

Eq. (5.1) is applicable only for γ = 15.45 ~ 17.4 kN/m^3 only.

5.2 Control of Soil Density

5.2.1 Air Pluviation of Backfill

To achieve a uniform soil density in the backfill, Ottawa sand was deposited by air-pluviation method into the soil bin to achieve the desired loose, medium, and dense states. The pluviation method had been widely used for a long period of time to reconstitute laboratory sand specimens. Rad and Tumay (1987) reported that pluviation is the method that provides reasonably homogeneous specimens with desired relative density. Lo Presti et al. (1992) reported that the pluviation method could be performed for greater specimens in less time. As indicated in Fig. 5.4, the soil hopper that lets the sand pass through a calibrated slot opening at the lower end was used for the spreading of sand. A photograph of the pluviating process is shown in Fig. 5.5. By choosing the appropriate sand-hopper slot opening and the drop height, different soil densities can be obtained. It should be mentioned that only the loose (D_r =35%) backfill was achieved in this study.

To achieve the desired loose, medium dense and dense backfills, the relationship between drop height of soil and soil density established by Lee (1998) was used. The relationship was built using three slot openings (5 mm, 10 mm and 15 mm) were adopted, and drop height of soil varied from 0.25 m to 2.5 m. Relative densities ranged from 16.5 % to about 100 % were achieved as shown in Fig. 5.6. It can be observed from the figure that with the same drop height (for example drop = 1.0 m), a wider slot opening tends to decrease the soil density. The phenomena can be explained by that during free-falling with a wider slot opening, sand grains impact one another more often and induce greater loss of kinetic energy. On the other hand, the drop distance also influences the relative density of the backfill. With the same slot opening, a greater drop distance would induce a denser backfill. Although the impact energies of sand grains will increase with increasing drop height, there is a limitation of particle speed increment as reaching terminal velocity due to forces of buoyancy and drag on the particle. (Vaid and D. Negussey, 1984)

Das (1994), suggested that relative densities of 35%, 60%, and 80% was defined as loose, medium dense, and dense condition, respectively. To obtain the desired loose, medium dense, and dense backfill, the slot openings and drop heights adopted are listed in Table. 5.2. For this study, to achieve the desired D_r =35%, the drop height of

1.0 m and slot opening of 15 mm are selected for air-pluviation.

5.2.2 Uniformity of Soil Density

At the beginning of the test, a layer of 100-mm thick Ottawa sand was placed in the soil bin. Then three density control boxes (as shown in Fig. 5.7), with 150 mm ╳ 150 mm ╳150 mm internal dimensions, were put into the soil bin on the surface of the backfill at the same elevation. The steel plates to fabricate the boxes are 10-mm thick. After soil had been poured to the desired elevation, the buried soil boxes were then dug out from the backfill carefully. Soil density in the box can be found by dividing the mass of soil in the box by the inside volume of the box.

Chen (1997) conducted a series of experiments to investigate the distribution of soil density in the air-pluviated soil mass (Fig. 5.8). Experimental results show the standard deviations of average density measured for loose, medium dense, and dense backfill were found to be 1.23%, 1.59% and 1.74% respectively. It is clear that the densities measured at the same elevation appear to be uniform.

To investigate the variation of density with depth, another group of tests was conducted. Four density control boxes were put into the soil bin at different depths of 90 mm, 340 mm, 590 mm, and 840 mm near the center of the soil bin (Fig. 5.9). After Ottawa sand was poured into the soil bin up to desired depth from the top of the soil bin, the boxes were dug out of soil mass carefully, and soil densities could be determined. Experimental results show that the standard deviations of average density measured for loose, medium dense, and dense backfill were found to be 1.36%, 1.73%, and 0.66%. From a practical point of view, it may be concluded from these tests that the soil density in soil bin is quite uniform.

5.3 Side Wall Friction

To constitute a plane strain condition for model wall tests, the shear stress between the backfill and sidewall should be minimized to nearly frictionless. To reduce the friction between sidewall and backfill, a lubrication layer with plastic sheets was furnished for all model wall experiments. Two types of plastic sheeting, one thick and two thin plastic sheets, were adopted to reduce the interface friction. All plastic sheets will be hung vertically on each sidewall before the backfill was deposited as shown in Fig. 5.10.

Multiple layers of thin plastic sheets (without any lubricant) were used by McElroy (1997) for shaking table tests of geosynthetic reinforced soil (GRS) slopes. Burgess (1999) used three thin plastic sheets to reduce side wall friction in full-scale GRS wall tests. The wall friction angle was approximately 15° as determined by the shear box tests. In this study, two thin and one thick plastic sheet were adopted for the earth pressure experiments. The friction angle developed between the plastic sheets and steel sidewall could be determined by the sliding block test. A schematic diagram and photograph of sliding block test proposed by Fang et al. (2004) are illustrated in Fig. 5.11 and Fig. 5.12. The interface angle by sliding block test is determined using basic principles of physics. Fig. 5.13 shows the variation of friction angle δ with normal stress σ for plastic sheet method used in this study. The measured friction angle with this method is about 7.5°. It should be noted that with the plastic – sheet lubrication method, the interface friction angle is nearly independent of the applied normal stress.