# Measurement of Tensile strength and the effect of finer particles

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## 1. Introduction

Recently, a new tensile strength measuring apparatus for measuring the tensile strength of soil has been introduced by Tamrakar et al. (2004). Accordingly the apparatus could be used for both saturated and unsaturated (compacted) soils. In addition, the apparatus is simple to use.

In this paper, tensile strength of saturated (NSF clay, DOTAN and the mixture of KIBUSHI clay and SEKIEI silt) and compacted (mixtures of Kaoline-Silt, Silt-Sand and Sand-Kaoline in different proportions) soils is measured and the effect of amount and size of the soil particles in the tensile strength is studied. Unconfined compression tests are also performed and they are compared with the tensile strength.

## 2. Testing Apparatus

Tensile test apparatus shown in Photo 1 consists of a horizontal platform upon which a newly developed tensile mold is placed. This tensile mold consists of two separate “C” shaped forms which are almost circular in shape except at the middle portion where these two halves are joined. Minimum width at this minimum portion is 3 cm. Depth of the mold is 5 cm. The attachment of one of the box to the horizontal platform is fixed while another box can freely move on to the platform in the horizontal direction. To reduce the friction between the movable body and the platform which was about 70 gram-force, linear sliding roller is placed in between. Movable box is pulled out by the motor attached with the horizontal platform.

## 3. Specimen Preparation and Installation Process

Saturated specimens of NSF clay (Kaoline), DOTAN and mixtures of KIBUSHI Clay and SEKIEI Silt are prepared by mixing them with distilled water at 2.5 times of their liquid limit and consolidated in a special mold (tamrakar et al., 2004) under different consolidation pressures; 50 kPa for Dotan and 100, 200 and 300 kPa for Kaoline and the mixtures of KIBUSHI Clay and SEKIEI Silt. Then they are directly pushed into the tensile mold with sufficient attention. Wire saw is used for cutting and trimming of the specimen.

Compacted specimens of Kaoline-Silt, Silt-Sand and Kaoline-Sand are prepared by thorough mixing, maintaining the water content around 10%. Then they are kept in the air tight plastic bags for several days so that homogeneity in water distribution could be obtained. Static compaction is done by putting the predetermined amount of mixed materials (dry density is fixed) into the tensile mold. Dry density maintained for the mixtures of Kaoline-Silt, Silt-Sand and Kaoline-Sand are 1.5, 1.4 and 1.5 g/cm$^3$ respectively. Water content for all the compacted specimens are maintained at 10%

Before putting the specimens into the tensile mold in both the compacted and saturated tests, a thin film of grease is applied on the inner surfaces of tensile mold and the inner bottom surface of the body in order to minimize the friction between the inner surfaces of mold and the specimen. After that the two halves of the tensile mold are screwed to the body. The movable

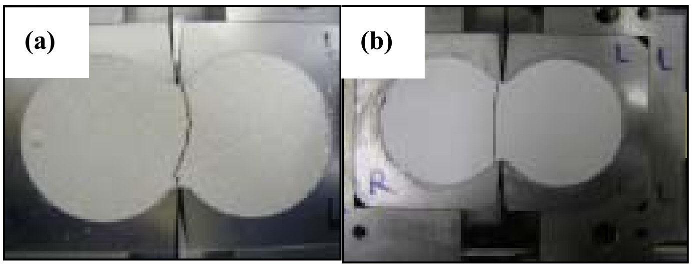

Photo 1 (a) Compacted soil and (b) Saturated NSF-Clay

Tensile strength, Unconfined compressive strength, NSF Clay, Compacted soil
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body is fixed by screwing it to the horizontal platform before the sample preparation. Once the specimen preparation is finished, then load cell is attached at the movable body towards the pulling direction. Finally, movable body is freed and pulling is done by rotating the motor at the constant speed of 0.35mm/min. Unconfined compression tests are also performed for both saturated and compacted specimens.

**4. Test Results and Discussion**

Tensile cracks developed during the tests of compacted and saturated specimens are shown in Photo 1. Figure 1 shows the tensile stress vs. displacement curve obtained for saturated DOTAN clay consolidated at 50.2 kPa. From the graph, it is obvious that a clear stress-displacement curve could be obtained using this new tensile measuring apparatus.

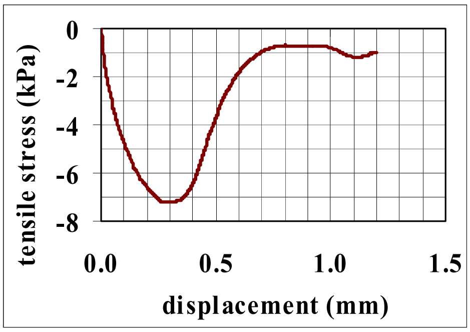


Fig. 1 Tensile stress~displacement curve

Table 1 shows the tensile strength ($q_t$) and compressive strength ($q_u$) obtained for saturated NSF-clay and the mixture of KIBUSHI Clay and SEKIEI Silt. As shown in the table, the ratio of $q_u/q_t$ of NSG clay is around 3 where as that for the mixture is around 4.

Table 1 $q_u$ and $q_t$ of Saturated soils

| Consolidation (kPa) | $q_u$ (kPa) | $q_t$ (kPa) | $q_u/q_t$ |
|---|---|---|---|
| NSF-clay | | | |
| 100 | 29.9 | 8.7 | 3.4 |
| 200 | 52.8 | 21.3 | 2.5 |
| 300 | 73.1 | 26.0 | 2.8 |
| KIBUSHI Clay : SEKIEI Silt | | | |
| 100 | 43.1 | 11.4 | 3.8 |
| 200 | 122.9 | 29.3 | 4.2 |
| 300 | 135.5 | 33.8 | 4.0 |

Tables 2, 3 and 4 show the $q_t$ and $q_u$ measured for Kaoline-Silt, Silt-Sand and Kaoline-Sand mixtures. In each table, it could be observed that there is increase in strength with the increase in the amount of finer particles (Kaoline in case of Kaline-Silt and Kaoline-Sand and Silt in case of Silt-Sand mixture). Among these three types of mixtures, Kaoline-Silt mixture which has the highest amount of finer particles, shows the highest values of strength than those by other two mixtures. Silt-Sand mixture shows the lowest value. Comparing the strength values and the ratio of strengths ($q_u/q_t$) of Kaoline-Silt and Kaoline-Sand (Tables 2 and 4), it could be seen that at the same % of Kaoline, the strength of Kaoline-Silt mixture is higher than that for Kaoline-Sand mixture. This means that the soil containing the smaller size of the finer particles gives shows the higher value of strength.

Table 2 Kaoline-Silt (CFP) mixture

| % of Kaoline | $q_u$ (kPa) | $q_t$ (kPa) | $q_u/q_t$ |
|---|---|---|---|
| 25 | 63.6 | 6.8 | 9.3 |
| 40 | 97.4 | 8.2 | 11.8 |
| 50 | 119.9 | 9.2 | 13.0 |
| 60 | 142.4 | 10.1 | 14.0 |
| 75 | 176.2 | 11.6 | 15.2 |

Table 3 Silt (CFP)-Sand mixture

| Silt(%) | $q_u$ (kPa) | $q_t$ (kPa) | $q_u/q_t$ |
|---|---|---|---|
| 25 | 6.6 | 3.0 | 2.2 |
| 30 | 8.4 | 3.2 | 2.7 |
| 40 | 12.1 | 3.4 | 3.6 |
| 50 | 15.8 | 3.7 | 4.3 |
| 60 | 19.5 | 3.9 | 5.0 |
| 70 | 23.2 | 4.2 | 5.6 |
| 75 | 25.0 | 4.3 | 5.8 |

**5. Conclusions**

1. Measurement of tensile strength for both saturated and compacted soils are possible by this new tensile strength measuring apparatus.
2. From the test results of Kaoline-Silt, Silt-Sand and Kaoline-Sand mixtures, it could be said that with the increase in the amount of finer particles, the ratio of $q_u/q_t$ increases. But with the increase in the size of finer particles there is decrease in the strength ratio.
3. The ratio of $q_u/q_t$ for saturated NSF clay and the mixture of KIBUSHI Clay and SEKIEI Silt are around 3 and 4 respectively. Tensile strength of saturated DOTAN (consolidated at 50.2 kPa) shows 7.2 kPa .

Table 4 Kaoline-Sand mixture

| % of Kaoline | $q_u$ (kPa) | $q_t$ (kPa) | $q_u/q_t$ |
|---|---|---|---|
| 25 | 21.4 | 4.1 | 5.2 |
| 30 | 32.3 | 4.8 | 6.7 |
| 35 | 43.3 | 5.6 | 7.7 |
| 40 | 54.2 | 6.4 | 8.5 |
| 45 | 65.2 | 7.1 | 9.1 |
| 50 | 76.1 | 7.9 | 9.7 |
| 55 | 87.1 | 8.6 | 10.1 |
| 60 | 98.0 | 9.4 | 10.4 |
| 65 | 109.0 | 10.2 | 10.7 |
| 75 | 130.9 | 11.7 | 11.2 |

**References**

Tamrakar, S.B., Toyosawa, T. and Itoh, K., 2004: Tensile strength of Compacted and Saturated soils using newly developed tensile strength apparatus, 59th JSCE National Conference, 3-279, pp. 557-558.