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LID plastic underground water storage tanks engineering properties evaluation

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ABSTRACT

An underground water storage system is a useful and important LID best management practice for urban design. This system can be used to enhance water infiltration and reuse the recycled water. A series of vertical compression tests, the vertical compression creep test, and the cyclic shear test were conducted to evaluate the performance of two types of plastic storage systems. The compression strength, compression creep strain, the maximum shear resistance and damping coefficient size effects were evaluated for the tested products. The compression test results indicated that the ultimate compression strength decreases as the sample height increased. For the typical maximum 2.0 meters overburden condition, both plastic underground storage systems can provide more than 3.0 bearing safety capacity factor. The vertical creep strain from 1 to 1000 hours for both conditions under 36 kPa vertical compression load was about 1.0 mm and the creep strains versus log time curves was quite similar for all test conditions. The series cyclic direct shear test results indicated that the shear resistance and damping coefficient of Type B product slightly better than that for the type A product.

Keywords: Underground storage tank, Water storage, Low-impact development, LID, Sponge city, Water reuse, Geosynthetic, Polyolefin.

1 INTRODUCTION

Urbanization and development alter the surface water infiltration, percolation to groundwater, evapotranspiration, and transpiration natural hydrologic processes. Past traditional engineering approaches tended to route storm water runoff rapidly from developed surfaces into drainage systems, discharging storm flows and pollutants into downstream surface waters. To maintain and improve the main hydrologic functions after development, reducing the overall imperviousness of a site is one of the most important design strategies. That can be achieved in multiple ways including applying low impact development (LID) storm water management practices, alternative layouts of street design, and other methodologies for reducing the development of footprints and disconnecting directly connected impervious areas from the storm water collection systems.

LID works to replicate natural hydrologic processes and reduce the disruptive effects of urban development and runoff. LID has emerged as an alternative approach that is complimentary to conventional storm water management measures including storm water best management practice (BMPs) used to manage runoff. LID techniques can enhance infiltration, percolation, and evapotranspiration to reduce the adverse effects on surface water, encourage groundwater recharge, and enhance water quality. LID methods offer great versatility in design, and can be incorporated into new urban development, redevelopment designs and alternative transportation design with relative ease. LID methods offer great versatility in design, and can be incorporated into new urban development, redevelopment designs, and alternative transportation design with relative ease.

The most commonly used LID BMPs include bioretention areas, bioswales, permeable pavement, infiltration trench, planter boxes, stand filters, sand filters, vegetated filter strips, and vegetated swales. Curb cuts, diversion structures, hydraulic restriction layers, utilities, connectivity, and ADA requirements are common LID design elements. In addition, underground water storage system is also a useful and important LID BMP for urban design. This system can be used for enhancing water infiltration or reusing the recycled water.

2 PLASTIC STORAGE TANK SYSTEM CONSTRUCTION

Generally, the first step for underground plastic storage system installation is to excavate enough open space to accommodate the storage system design and compact the foundation soil. If an infiltration system is designed, a permeable non-woven geotextile will be placed at the bottom of the storage system. Otherwise, an impermeable liner will be placed at the bottom for a storage system. The individual storage units will then be stacked up according to the design system. Furthermore, the storage system will be wrapped around with permeable nonwoven geotextiles or impermeable geomembrane based upon the design purpose. In addition, flow piping, filter, and maintenance systems will also be installed. Finally, the storage system will be backfilled and covered up with overburden soil. For an underground storage system, the system will be subjected to long-term vertical dead load with different live loads, and some horizontal active earth pressure. During an earthquake the system could also be subjected to some cyclic horizonal loads.

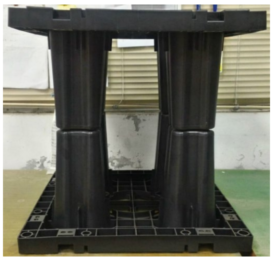
3 TEST PROGRAMS

In order to ensure the system is reliable during the design life. The ultimate vertical bearing capacity is the most important design item for all plastic underground storage system. The vertical compression strength data can be obtained in the brochures for those plastic underground storage systems from Japan, European, USA, and Taiwan. In order to evaluate the long-term vertical dead load resistance capability, 1000-hr vertical compression creep test is also a common evaluation item for plastic storage systems. This test data is limited to a few systems from Japan, Taiwan, and some other countries. In addition, cyclic shear resistance is an important evaluation item for plastic underground storage systems subjected to seismic loads. Up to now, this test method is only documented by the association specification in Japan and Taiwan. The test results can be seen in the technical manuals from Japan and Taiwan related associations. In addition, the damping coefficient was further determined based upon the data obtained from the cyclic direction shear test. The determined damping coefficient is strongly related the seismic resistance behavior of the storage system.

Beside the typical vertical compression test, the vertical compression creep test, and the cyclic shear test were conducted in this study, the size effect on compression strength, compression creep strain, and damping coefficient were also evaluated for the test products.

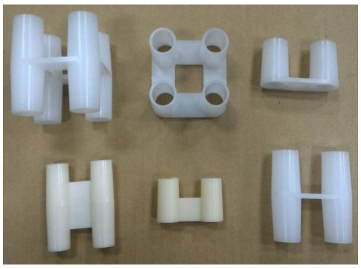
4 TEST MATERIALS

Two types of plastic storage tank systems were evaluated during the test programs. The typical dimensions and pictures of the test materials are shown in Table 1 and Figure 1. Type A product system can be connected using latch elements as shown in Figure 1. Type B product can be cross stacked-up and interlocked together to form a storage system without any other connecting attachments.

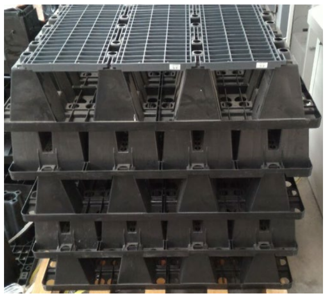


(a) Type A system unit

(c) Type B system unit



(b) Type A connection parts



(d) Assembled Type B system

Figure 1 Type A and Type B storage systems

Table1 Dimensions of Type A and Type B units

Type	Length (mm)	Width (mm)	Height (mm)	Unit Weight (kN/m^3)
A	500	500	500	439.5
B	994	994	220	373.0

5 RESULTS AND DISCUSSIONS

A series of vertical parallel plate compression tests were conducted for the two storage tank systems. The compression test was conducted according to the modified JIS K 7181 or related ASTM test methods. The compression rate is 10 mm ± 3 mm/min. A minimum of 3 samples were conducted for each test condition. The height effect on compression strength was evaluated for the Type A product. Four different height samples were used in the evaluation program. The sample heights varied from 0.5 to 2.0 meters. The compression test results are shown in Figure 2. The results indicated that the ultimate compression strength decreases as the sample height increased. Buckling behavior can be observed in the compression tests for the 2.0-meter sample height. However, the difference in compression strength is very limited for the conditions between 1.0 and 1.5 meters. Therefore, compression tests with a sample height of 1.0 meter are recommended for the Taiwan Sewage Association technical manual. Based upon this criterion, the compression strength of the Type A and Type B storage systems are 431 kPa and 108 kPa, respectively. For the typical maximum 2.0 meters overburden condition, both plastic underground storage systems can provide more than 3.0 safety factor bearing capacity.

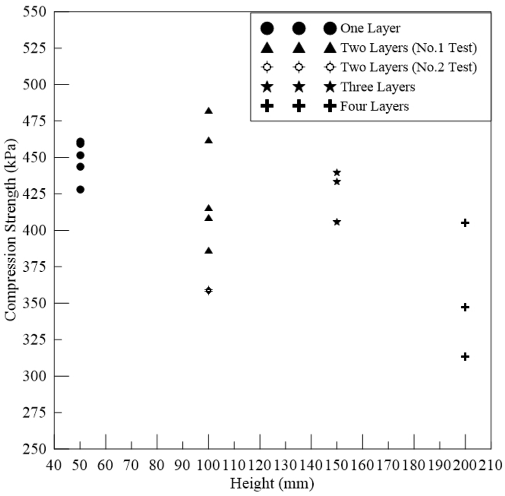
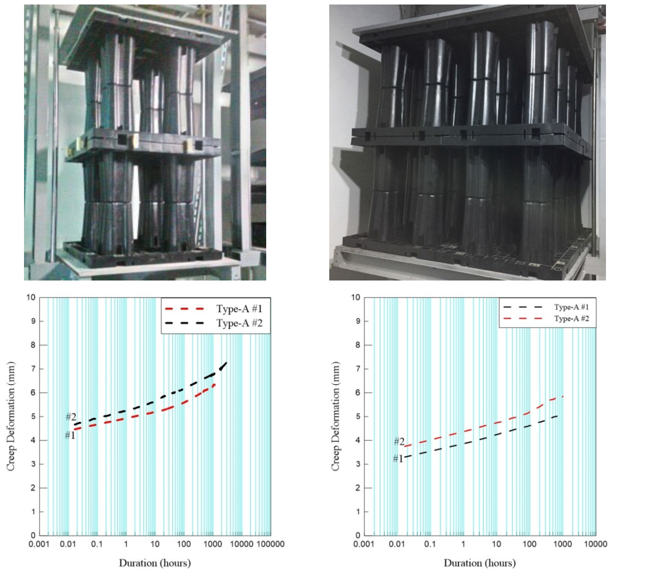


Figure 2 Compression strengths of Type A system with different heights

In order to evaluate the long-term compression resistance of the test plastic underground storage system, a minimum 1000 hours parallel plate compression creep test is commonly conducted in a constant 23o C temperature condition. A 36 kPa vertical compression load was applied for all samples. A sample size of 500 mm x 500 mm x 1000mm and 1000 mm x 1000 mm x 1000 mm was used. The creep test results for both Type A product sample sizes are shown in Figure 3. As shown in the figure, the vertical creep strain from 10 to 1000 hours was about 1.0 mm and the creep strains versus log time curves were quite similar for both sample cases. The test results also implied that the sample size has almost no influence on the creep strain for the Type A product under these test conditions.

A series cyclic direct shear tests were conducted for large dimension Type A and Type B product samples. The general wide-height-depth sample dimensions were 1500 mm x 2000 mm x 2000 mm. A 36 kPa equivalent to 2-meter vertical overburden compression load was applied during the entire test program. In addition, a horizontal step increased cyclic shear displacement was applied using a strain-controlled motor with a constant 30 mm/min speed at the top of the plastic storage system.

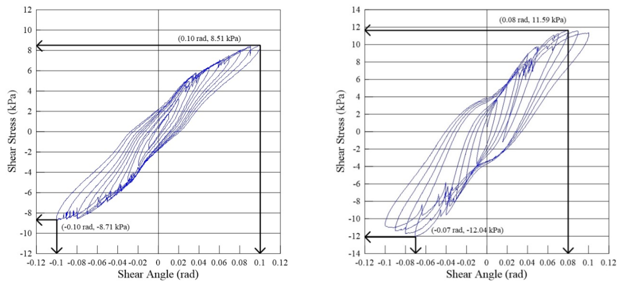


(a) 500mm×500mm×1000mm (b) 1000mm×1000mm×1000mm

Figure 3 Compression creep deformation curves for samples of 500mm×500mm×1000mm and 1000mm×1000mm×1000mm for the Type A system.

(a) 1500mm×2000mm×2000mm Type A system

(b) 1500mm×2000mm×2000mm Type B system



(c) Hystersis loops of Type A system (d) Hystersis loops of Type B system

Figure 4 Hystersis stress loops of cyclic tensile tests of the Type A and the Type B storage systems.

The horizontal shearing resistance was measured using a load cell attached to the electric motor. The step cyclic incrementally horizontal angle was ±1% rad until the sample failed or the horizontal angle reached ±10 % rad. The typical hysteresis horizontal angle verses shear resistance curves Type A and Type B products are presented in Figure 4. The maximum shear resistance and associated damping coefficients for both systems for different depths for Type A and Type B products are summarized in Table 2. The results indicated that the Type B product showed a slightly better performance both in shear resistance and damping coefficient that that for the Type A product.

Table 2 Average maximum shear strengths and damping coefficients of Type A and Type B products for different depths with dimensions of 2000mm in width and 2000mm in height.

System Type	Depth (mm)	τ_{max} (kPa)	ξ
A	2000	8.61	0.114
	1500	8.65	0.108
	1000	7.79	0.120
B	2000	11.82	0.145
	1500	11.23	0.156
	1000	10.02	0.150

6 SUMMARY AND CONCLUSIONS

Urbanization and development alter the natural surface water infiltration, percolation to groundwater, evapotranspiration, and transpiration hydrologic processes. LID techniques can enhance infiltration, percolation, and evapotranspiration to reduce the adverse effects on surface water, encourage groundwater recharge, and enhance water quality. An underground water storage system is also a useful and important LID BMP for urban design. Two types of plastic storage tank systems were evaluated during these test programs. A series typical vertical compression test, the vertical compression creep test, and the cyclic shear test were conducted. In addition, the size effect on compression strength, compression creep strain, and damping coefficient were also evaluated for the tested products.

The compression test results indicated that the ultimate compression strength decreases as the sample height is increased. The difference in compression strength is very limited for the conditions between 1.0 and 1.5 meters. Therefore, compression test with sample height of 1.0 meter was recommended in the following tests. The compression strength of the Type A and Type B storage systems are 431 kPa and 108 kPa, respectively. For the typical maximum 2.0 meters overburden condition, both plastic underground storage systems can provide more than 3.0 safety factor bearing capacity.

A series of compression creep tests were conducted for the Type A product with 36 kPa vertical compression load for all samples. Sample sizes of 500 mm x 500 mm x 1000mm and 1000 mm x 1000 mm x 1000 mm were used. The vertical creep strain from 10 to 1000 hours for both conditions were about 1.0 mm and the creep strains versus log time curves were similar to each other.

A series cyclic direct shear tests were conducted for Type A and Type B products with sample dimensions of 1500 mm x 2000 mm x 2000 mm. The shear resistance and damping coefficient of the Type B product were slightly better than that for the Type A product.

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