BY M. K. YEGIAN and A. M. LAHLAF

Geomembranes as base isolation

During the past decade, significant advancements have been made in our understanding of the behavior of geosynthetic-soil systems under static loads. Analytical procedures that incorporate the static-shear strength properties of geosynthetic-soil interfaces are used in the design of containment systems to ensure safety against slope-stability failures.

Although increased attention has been placed on static-stability concerns associated with geosynthetic soil systems, the seismic response of facilities that incorporate geosynthetics has not been adequately addressed.

During the past two years, we have been involved in research on the dynamic interface properties between geosynthetics (Lahlaf and Yegian, 1991, and Yegian and Lahlaf, 1992 a). Laboratory static-shear strength tests and shaking table tests were performed to estimate the static and dynamic-friction angles, respectively, between different geosynthetics.

The static test results confirm the observations made by other investigators—that the static-friction angle between a smooth geomembrane and a geotextile or another geomembrane is small.

For example, the measured-friction angles between a smooth high-density polyethylene (HDPE) geomembrane and a geotextile or between two smooth HDPE geomembranes were 10.7 degrees and 11.9 degrees respectively.

Furthermore, when the geomembrane was slightly lubricated, the angle-of-friction between two smooth HDPE geomembranes was as small as 8 degrees. Yegian and Lahlaf (1992b) have demonstrated that the interface-shear strength properties between smooth geomembranes are very sensitive to handling. Merely touching the geomembrane during testing can leave enough perspiration on its surface to lubricate it, thus significantly reducing the measured angle of friction.

The results of shaking-table tests on geomembrane-geotextile and geomembrane-geomembrane interface systems demonstrate that under dynamic loads, a limited-shear force is transmitted from a geomembrane to a geotextile or to another geomembrane.

Once this low-interface friction force is exceeded, permanent deformations are accumulated along the geosynthetic interface.

Thus, concern about the seismic response of a geotechnical facility that incorporates such geosynthetic systems should be primarily associated with relative displacements that may accumulate at the geosynthetic interface during the seismic event.

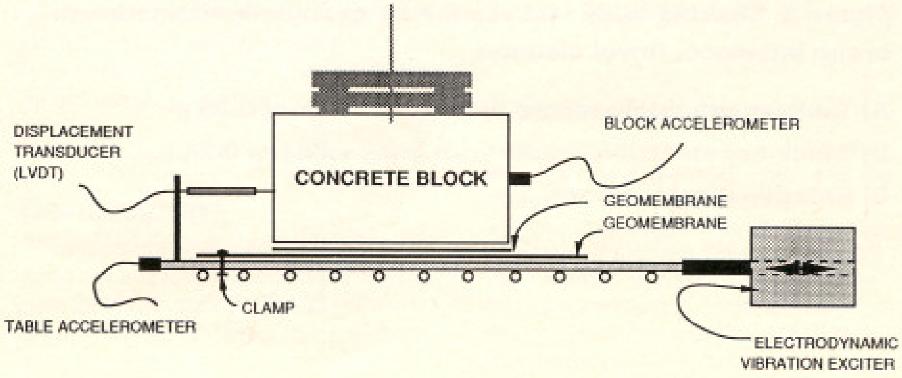
Because of the very low friction angle between geomembranes, and the observation of sliding along the geosynthetic interface during shaking-table tests, the concern about the low-interface friction angle can be an advantage in certain situations during an earthquake. This led to the development of the concept of using two layers of smooth geomembrane as base isolation for seismic hazard mitigation.

For example, the use of two sheets of geomembrane along the bottom of an embankment can isolate the embankment from the earthquake ground motions by allowing one geomembrane to slide on top of the other.

The concept of base isolation

For many years, structural earthquake engineers have been developing mechanical-base isolators for buildings and bridges. Fundamentally, seismic isolation of a structure is to achieve a discontinuity between the ground and the structure, so as to limit the levels of

Fig. 1 Shaking table apparatus



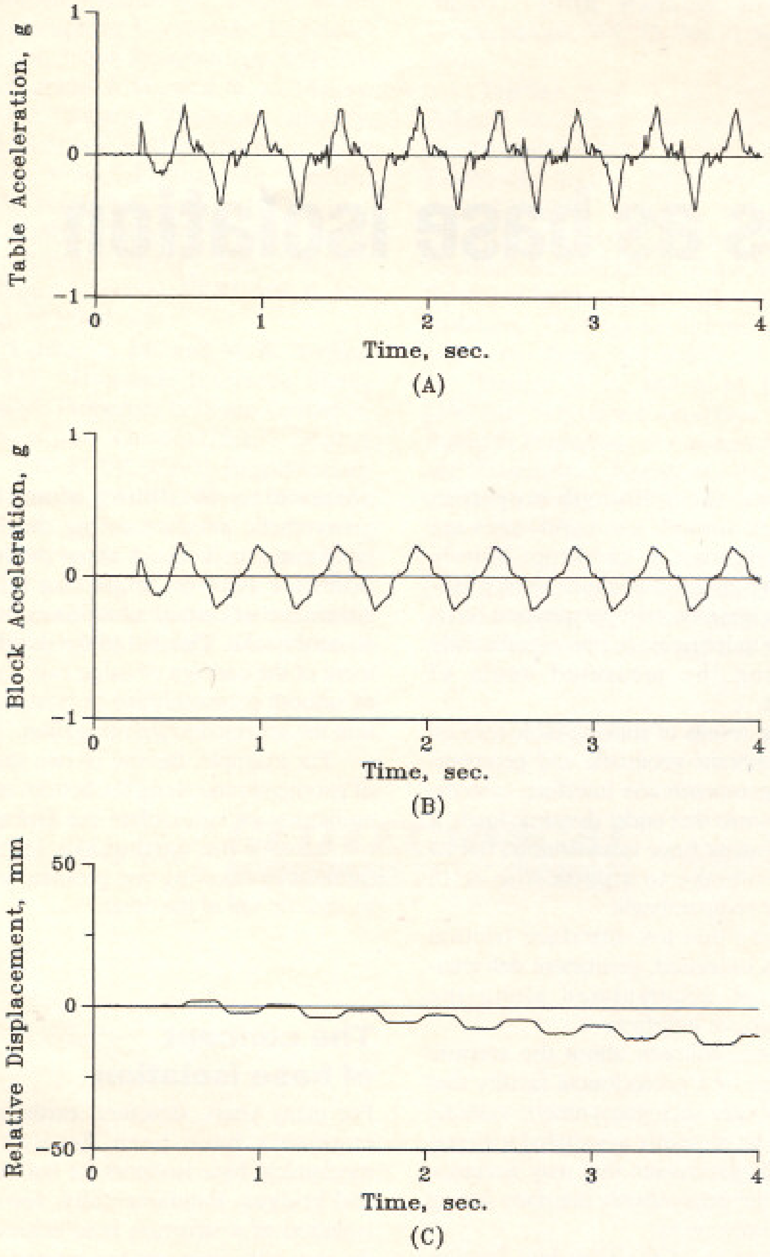


Figure 2 Shaking table test results for geomembrane-geomembrane interface, towel cleaned

A) Table acceleration record with peak value of 0.38 g

B) Block acceleration record with peak value of 0.24 g

C) Relative displacement.

the transmitted force and acceleration from the ground to the structure.

The concept of base isolation has been around for quite some time. Buckle and Mayes (1990) reported that designs for an earthquake-proof building, consisting of a rigid base-plate to carry the building, sitting freely on a mass of spherical bodies of hard material, was proposed in 1906.

Other isolation systems have been reported, offering varying degrees of feasibility and practicality. Mayes et al. (1984) reported, however, that until recently, seismic-base isolation has not found much application because of the difficulties entailed with isolation hardware and the large relative displacements that occur between the ground and the structure with some isolation systems.

To date, the concept of base isolation has been used mainly in the design of new buildings and bridges. Way and Howard (1990) reported that base isolation also has been used for seismic rehabilitation of existing buildings, and Kelly (1990) and Tajirian et al. (1990) reported cases of nuclear power plants built on isolation systems.

The research we have conducted demonstrates the use of geosynthetics also can provide isolation of certain geotechnical facilities, such as embankments and mat foundations from ground motions.

Using geosynthetics as base isolation in geotechnical earthquake engineering can be cost-effective, especially in high-seismicity regions. For example, a horizontally placed geosynthetic system that can limit the transmitted acceleration to 0.20 g can be of major benefit in seismic hazard mitigation for embankments, since most such facilities can adequately withstand 0.20 g.

Associated with this benefit is that along the geosynthetic interface, permanent displacement will be accumulated. However, the level of permanent displacement associated with such a geosynthetic-base isolation during an earthquake causing peak ground acceleration as large as 0.50 g would be less than a few inches, as can be observed from Newmark's (1965) results for symmetrical resistance.

Isolation of masonry buildings is another potential application of geomembranes. Arya (1984) observed during dynamic tests that damage caused by sinusoidal excitations on

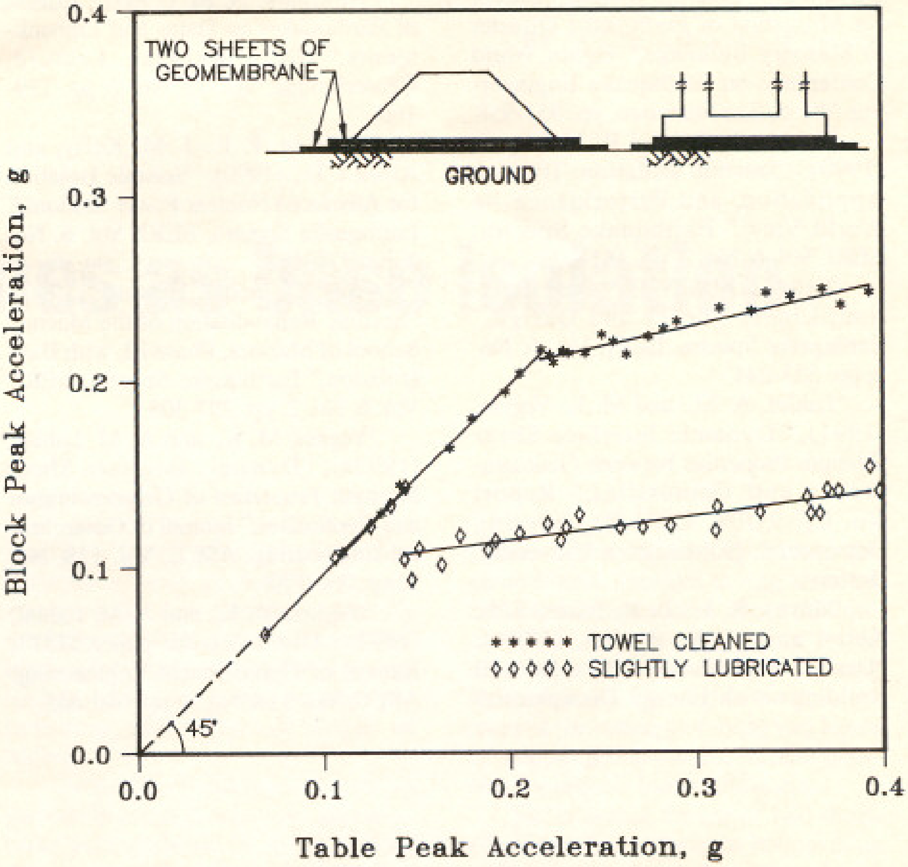


Figure 3 Block acceleration versus table acceleration for a frequency of f=2 Hz, and a Normal Stress = 1.2 psi.

half-size one-story masonry buildings, that were allowed to slip on the shaking table, was much less than in conventionally strengthened specimens.

In many parts of the world, where, for economic or other reasons unreinforced masonry or brick construction continues to be the practice, especially for residential houses, the structural damage resulting from an earthquake could be devastating.

Geosynthetics used as base isolators in such geographical areas appears to be an attractive and inexpensive way to mitigate the earthquake hazard.

To demonstrate the concept's technical feasibility, shaking-table test results are presented. Figure 1 shows the experimental set-up of the shaking-table facility used to measure the limiting-shear force that could be transmitted along the interface of two smooth geomembranes.

The acceleration of the table, upon which had a sheet of HDPE geomembrane was attached and that of a sliding rigid block to the bottom of which another sheet of geomembrane was glued were measured.

In addition, the relative displacements (slip) along the geomembrane interface was measured using a linear variable displacement transducer (LVDT).

Figure 2 shows a typical record of the measured data. Note that when the table peak acceleration was 0.38 g (figure 2A), the block peak acceleration was 0.24 g (figure 2B). Because the block acceleration was smaller than the table acceleration, relative displacement was induced between the table and the block (along the geomembrane interface) and was recorded by the LVDT (figure 2C). This is evidence that there is a limiting level of dynamic-shear force, hence, acceleration that can be transmitted to a structure placed on two sheets of geomembrane.

Other similar tests were performed where the table peak acceleration was varied between 0.05 g and 0.40 g. Figure 3 shows accelerations transmitted to the block as a function of the table acceleration for two surface conditions—towel cleaned and slightly lubricated (with Teflon spray).

The results show that the block moves with the table up to a limiting acceleration of 0.22 g for the towel-cleaned condition and 0.14 g for the slightly lubricated condition, as shown by the two lines inclined at 45 degrees. Once the limiting acceleration is exceeded, relative displacement occurs at the geomembrane interface, resulting in block acceleration smaller than the table acceleration as shown on figure 3.

For example, when the table peak acceleration was 0.40 g, the block peak acceleration was only 0.24 g for the towel-cleaned condition and 0.15 g, for the slightly lubricated condition. These test results demonstrate that two sheets of smooth HDPE geomembrane can isolate ground motions effectively to levels below 0.24 g or 0.15 g depending on the surface condition.

Conclusion

Shaking-table tests have been conducted to demonstrate the concept of using two sheets of smooth HDPE geomembrane as base isolation in earthquake hazard mitigation.

The test results show the shear force that can be transmitted from one geomembrane to another is limited. Thus, smooth geomembranes can be used to reduce earthquake-induced motions transmitted to geotechnical facilities.

The test results reported are for smooth HDPE geomembranes. Further research directed at achieving economic and technical feasibility of the proposed concept may lead to manufacturing of even smoother geosynthetics that may limit transmitted accelerations to less than 0.1 g.

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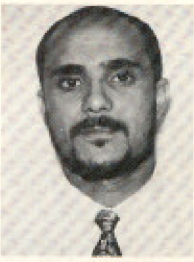

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