Geosynthetics in seismic applications

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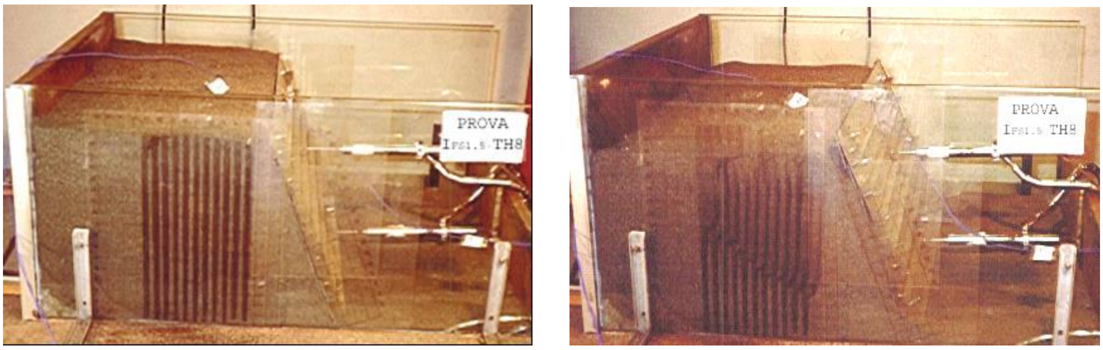
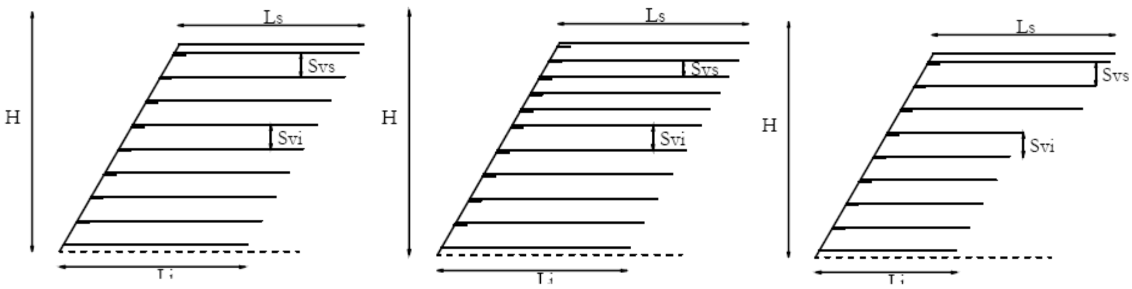
Due to the increasing value of the design acceleration, the use of geosynthetics is increasing around the world, especially after the 1995 Kobe earthquake. Geosynthetic reinforcement can be used for reinforced retaining walls, slopes stabilization, reinforced embankment, foundation reinforced soil, pile foundation with reinforced capping, etc. A great number of experimental tests have been carried out in the last years using shaking table facilities or geotechnical centrifuges. In the tests a reduced scale model of geosynthetic reinforced retaining wall is subjected to an artificial excitation (input motion) simulating the ground motion induced by an earthquake. During the test the displacement and acceleration response of the model are monitored as well as the tensile stress and strain in the reinforcement. The use of geogrid reinforcements in the model set-up allow to increase the input acceleration level required to bring the model to a serviceability or to an ultimate limit state. Moreover, the type of the reinforcement and its spacing significantly affect the response of the model in terms of cumulated permanent displacement. Physical modeling on full scale and reduced scale models can be used for understanding the reinforced-soil behavior subjected to earthquakes. Fig. 1 shows the behavior of a reduced scale reinforced model before and after the shaking applied in a shaking table. To increase the resistance to earthquakes a length of the upper geogrids could be increased or alternatively the spacing could be reduced at the top of the reinforced wall (see Fig. 2)



a) b)

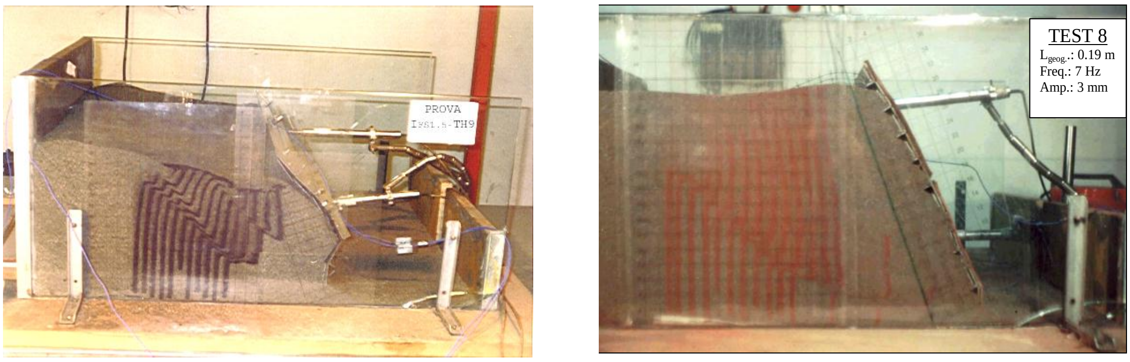
Fig. 1 Shaking table test on a geogrid-reinforced wall model: a) before the shaking; b) after the shaking



a) b) c)

Fig. 2: a) uniform lenght and uniform spaced reinforcements; b) uniform lenght reinforcements with reduced spacing at the top; c) uniform spaced reinforcements with increased length at the top.

Fig.3 shows the result of two shaking table tests carried out on two different wall models realized with the same geometry and the same soil but using two different dispositions of the geogrid reinforcements. In the first (Fig. 3a) the reinforcement were placed uniformly along the wall height and the model experiences large permanent displacements until failure. In the second (Fig.3) the reinforcement spacing was reduced in the upper part of the model and the wall permanent displacements significantly reduces avoiding the serviceability or the ultimate limit state.



a) b)

Fig. 3. Response of different reinforced type wall to the same seismic excitation: a) failure of a wall with uniform length and uniform spaced reinforcements; b) acceptable permanent displacement of a wall with uniform length and reduced spacing of reinforcements in the upper part of the wall.

The seismic design of the geosynthetic-reinforced retaining structures can be performed using the displacement-based approach in the light of the performance-based design. For a given design earthquake, the magnitude d of the permanent displacements suffered by the wall can be computed using the following relationships:

$$d = \frac{3 \cdot PGV^2}{PGA} \cdot \frac{k_{max}}{k_c} \quad \text{if } \frac{k_c}{k_{max}} \le 0{,}16 \qquad d = \frac{5 \cdot PGV^2}{PGA} \cdot \left(\frac{k_{max}}{k_c}\right)^2 \quad \text{if } \frac{k_c}{k_{max}} > 0{,}16$$

being $PGA = k_{max} \cdot g$ and PGV the peak ground acceleration and velocity of the design earthquake, respectively, and k_c the critical acceleration coefficient of the wall. k_c can be computed detecting the value of the pseudo-static coefficient which reduce to unity the pseudo-static safety factor.

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