Allan Block Passes Earthquake Test

Seismic research confirms structural capabilities of Allan Block Walls under heavy earthquake conditions.

Since their introduction to the engineering community in the late 1980's, Segmental Retaining Walls have captured an ever increasing share of the structural wall market. SRW structures are typically faced with modular, interlocking, concrete block units connected to layers of geosynthetics placed in the infill soils. The blocks provide a "hard armor facing" and the geogrids tie the soil mass together to create a stable structure. SRW walls provide engineers and site developers an alternative to cast-in-place concrete that is more aesthetic, easier to design and construct, and typically 20% to 30% less costly.

In a little more than a decade, the concrete block industry has produced and shipped over 500 million square feet of SRW to the market. Much of the block has gone into reinforced structures, with some walls exceeding 40 feet in height. "The overall value of SRW is driving the market" says Mark Hogan, President of the National Concrete Masonry Association (NCMA). "Industry indicators tell us that annual sales should continue to grow, as more builders, developers and engineers embrace SRW as a preferred solution for wall design and construction."

Current design methodology for SRW has been developed by industry and academic experts using empirical data and small-scale model tests. Testing has been limited to the individual components - long term strain on grids, shear capacity of block units, and block-to-grid connection. Design standards have evolved by taking the resulting values and combining them with modified variations of Coulomb active earth pressure methodology.

How does current SRW design methodology compare to real life performance? What are the actual forces present within an SRW structure? How would an SRW perform under the most aggressive circumstances possible - an earthquake?

To answer these questions, ALLAN BLOCK CORPORATION, together with HUESKER GEOSYNTHETICS, sponsored Columbia University on the first full-scale seismic testing ever performed on SRW walls. In the Fall of 2002, a series of three tests were conducted on Allan Block walls reinforced with Huesker geogrids at a seismic research facility in Japan.

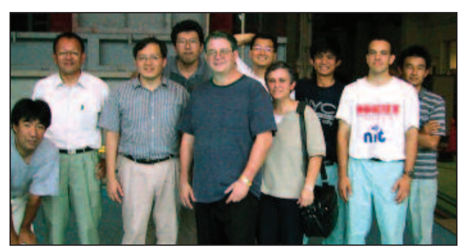
Here are the results.

RESEARCH TEAM

Principle Investigators

Professor Hoe Ling,
Department of Civil Engineering,
Columbia University.

Professor Dov Leshchinsky,
Department of Civil Engineering,
University of Delaware.



Chief Collaborators

Dr. Yoshiyki Mohri,
National Research Institute of Agricultural Engineering, Japan
Ministry of Agriculture, Forestry and Fisheries.

Mr. Kenichi Matsushima, NRIAE
Dr. Mutsuo Takeuchi, NRIAE
Structural Division

Professor Hoe Ling of Columbia University initiated the research project by a receiving a Career Award from the National Science Foundation. This provided the impetus to consider full-scale SRW wall testing on a shaking table, an undertaking never before attempted. Ling assembled a team of academics with strong backgrounds in geotechnical and structural research. "The scope and scale of this research project is the largest of its kind. We were excited to test the limits of SRW walls and compare them to current design methodology." Says Ling.

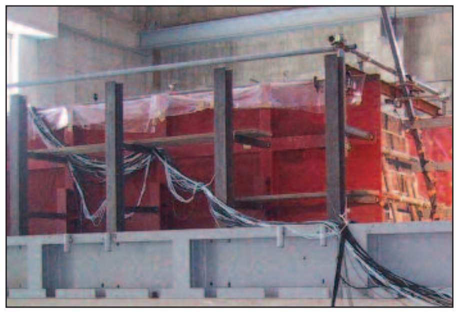
Professor Leshchinsky has been investigating stabilized earth structures for over twenty-five years. "Having spent much of my professional career analyzing the behavior and performance of soils and soil properties, I was thrilled to participate in such an endeavor. We knew the best way to understand and realize the structural qualities of an SRW wall was to build a full-sized, fully instrumented wall, and expose it to aggressive seismic forces. To find the true limitations of a structure, you need real life data." said Leshchinsky.

"When Allan Block agreed to sponsor the project, I knew we were on the way to finding data that would answer many questions on SRW performance."

FACILITIES

The research project was conducted on a large-scale shaking table facility built in Tsukuba, Japan in 1996 in the aftermath of the Kobe Earthquake. The table is 6m x 4m and capable of handling forces up to 50 ton-force (500 kN) with maximum horizontal and vertical accelerations of 1g. The facility is operated under the auspices of the Japan National Research Institute of Agricultural Engineering (NRIAE), and under the direction of Dr Mohri.

A steel bin was constructed to enclose the two sides and the back of the shaking table to confine the infill and backfill soils as the test structures were built. A poly lining on the inside



of the steel side walls minimized the effects of friction between the steel and the soils during the shaking.

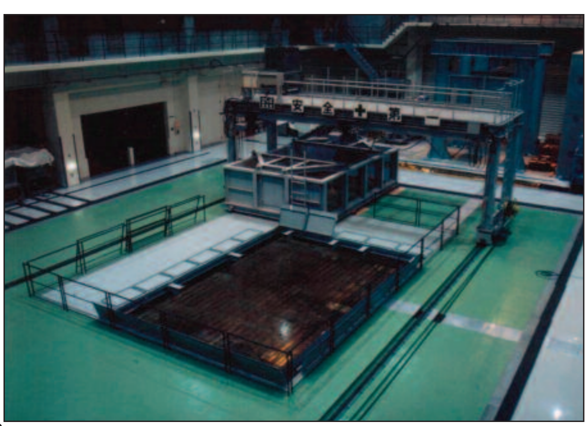
TESTING SCOPE

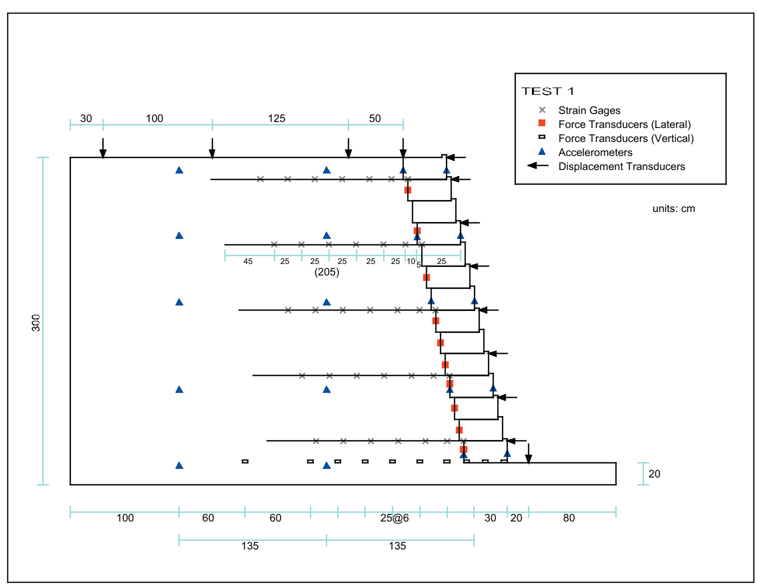
After much discussion, the Team defined the Stated Purpose of Study.

- To observe the performance of AB SRW under large earthquake excitation, up to the Kobe earthquake records.
- To investigate the effects of various design variables, such as vertical spacing, length and strength of geogrid, and accelerations on the wall performance.
- To refine existing design procedures and to remove over-conservatism inherent in many SRW codes.
- To establish experimental credentials for subsequent testing and research.

Tim Bott, Director of Engineering at Allan Block Corp, participated in the development of the Scope. "Of particular interest to our company was the performance of the block-to-grid connection." said Bott. "Much has been said about the value of "connection strength", and many in the industry have suggested that a "mechanical connector" was essential to system integrity. At ABC, we have long been an advocate for the "Rock-Lock" frictional connection found in our system, and we felt this research would validate our methods."

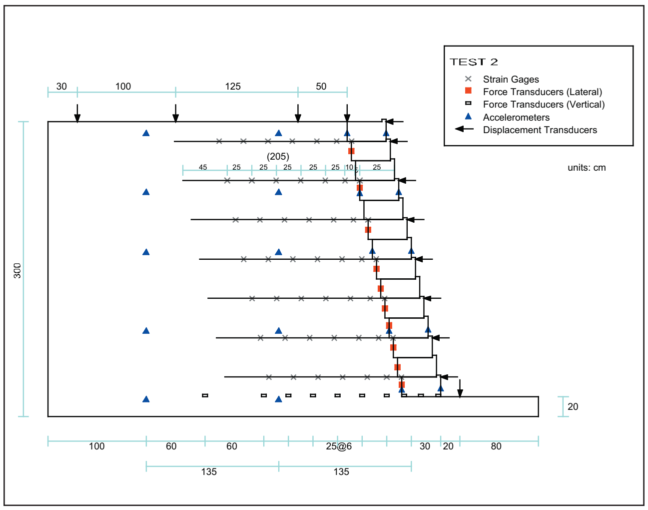
Ling and Leshchinsky proposed a series of three tests. The walls would be constructed with Allan Block facing units and Huesker geogrids to a maximum height of 2.8m over 0.2m thick foundation soil. Sandy infill soils with an internal friction angle of 38 were used to backfill the structures. Each wall would be heavily instrumented within the soil mass to measure actual loads and forces. Additional gauges would be placed to measure wall movement and displacement during and after the shaking. On walls One and Two, horizontal accelerations would be applied. On wall





Three, both horizontal and vertical excitation would be applied.

Test One was designed as the benchmark. The first layer of grid was placed on the first course, and subsequent layers were placed at every third course (60cm), with lengths of .73H (.73 times the total wall height). This configuration of spacing and embedment length is common to current design within the industry.



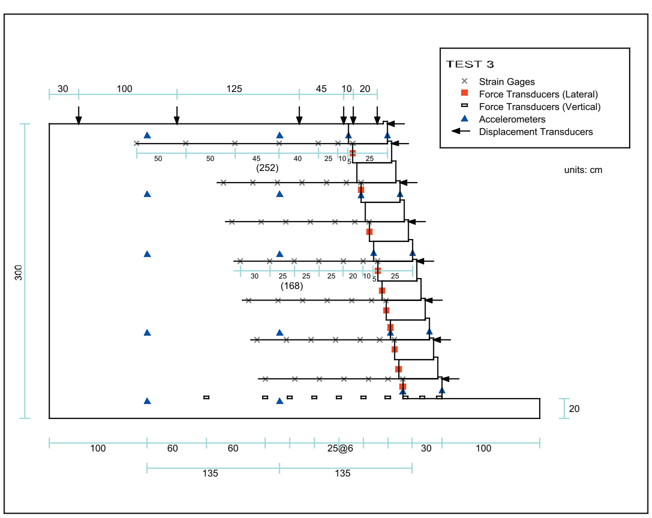
Test Two was built in exactly the same manner as Test One, with the only change found in the grid spacing. The objective was to provide an accurate assessment of the influence of spacing on SRW design. Using the same embedment length, grid layers were placed on every other course of block.

Test Three was designed to study the added effects of vertical acceleration, and to accurately simulate actual earthquake events. In this test, the grid lengths were reduced to .6H in all but the top layer, with the two course spacing maintained as in Test Two. To accommodate the anticipated effects of the vertical acceleration, the length of the top layer of grid was increased to .9H, and a grouted connection was introduced at this layer only. The standard "Rock-Lock" connection was considered sufficient for the lower layers of grid.

TESTING RESULTS

Test One

Dov Leshchinsky "We designed Test One to accept an initial horizontal acceleration of .4g. Based on current design assumptions, we expected to see significant deformations after the shaking, and even considered the idea of a full scale failure. However, once the .4g excitation was complete, we could not find any visible sign of change in the blocks, the wall, or the soil mass. Only some hairline cracks at the back of the reinforced zone." After some discussion, the Team elected to apply a higher load of .8g to the wall to elicit some visual signs of distress. After the excitation, larger cracks were observed at the top of the backfill zone, immediately behind the infill zone. Hairline cracking was present in the infill soils, and the wall face had a total displacement of 70mm at the top of wall. Some minor settlement occurred behind the wall facing. "We fully expected wall failure in Test One during the .8g excitation." Said Ling. "All of us were surprised at the way the entire system performed."



Test Two

Test Two was constructed with the closer grid spacing, with all other elements remaining the same as before. Once again, at .4g, virtually no residual affects were seen after the shaking had occurred. With the .8g excitation, the Team watched as the wall moved fluidly with the horizontal accelerations, then resumed its original standing position.

> **"The connection between the block and grid performed perfectly"**
>
> *Tim Bott, Allan Block*

As anticipated, the closer spacing resulted in even less residual effects, with a total displacement of the wall facing of 0.5cm, and settlement behind the top block of 0.3cm. "The connection between the block and grid performed perfectly" said Bott. "When they disassembled the wall, we confirmed that the block-to-grid connection was entirely intact at every location". Leshchinsky commented on the shear key connection at the facing. "As each horizontal dynamic movement passed through the wall, we could see the shear key at the front of the Allan Blocks absorb the shock from the forces. No problems whatsoever."

Test Three

In Test Three, the Team planned to replicate the identical shaking pattern of the Kobe earthquake. "With the success of Tests One and Two behind us, we decided to put an optimal solution together for the final test." said Ling. "With vertical accelerations coming into play, we elected to go with the two block spacing. However, we felt a shorter grid length would be adequate, as measurements from the previous tests indicated very low stress values at the back of the grid layers." After some discussion about the effect of vertical accelerations at the top of the reinforced zone, the Team modified the final pattern to introduce a long layer of PVA grid at the top, with a 'grouted connection' as an added precaution. "We use this modified connection technique at top-of-wall for seismic design as an added safety factor for larger walls" said Bott. "It ensures that the block at the top won't experience a "lift-off" effect from the presence of large vertical accelerations." Test Three was run, and net effects on the wall were virtually the same as the first two. "It's amazing to me that we applied the same aggressive seismic forces to this wall as occurred in Kobe in 1996, and saw no significant deformation or breakdown in the structure." said Leshchinsky. "That earthquake measured 7.2 on the Richter scale and devastated many retaining walls and structures throughout the region."

OBSERVATIONS

Professor Hoe Ling "When properly designed and constructed, these systems seem well suited for handling seismic conditions. The wall facing, soil mass, and geosynthetic reinforcement all moved in phase with the earthquake induced forces. Structures that are both flexible and coherent are ideal for these conditions."

Professor Dov Leshchinsky "I am more convinced than ever that mechanically stabilized earth is a safe, reliable alternative to rigid structural design. This research should go a long way towards understanding the real-life mechanics of SRW walls. I would expect to see some changes in current design methodology once the data has been fully review by or peers."

Tim Bott "This research should stimulate a lot of discussion within our industry. The overall performance of these walls provides irrefutable proof that segmental retaining walls and mechanically stabilized earth are sound, safe and structurally reliable."

SUMMARY

These three tests confirmed the capabilities of SRW wall performance during seismic events. The data produced provides invaluable insight on the actual forces present in the wall facing, and in the reinforced soil zone behind. With time, the research team will be able to extend this information to others in the industry and in geotechnical research, to better understand how SRW walls work. From that analysis, we can expect further improvements in design methodology, and better acceptance from those in both the public and private sector.

SRW walls not only provide a more affordable, elegant, and efficient way to solve sight problems, they work better than we ever imagined.

The Research Team is moving on. Another series of tests are being planned for 2004 in Taiwan.