Department of Resources Recycling and Recovery

SCOPE OF WORK

Research to Determine the Bearing Capacity and Seismic Response of
Tire Derived Aggregate (TDA)

I. INTRODUCTION

CalRecycle has been working for over 20 years to develop civil engineering applications for Tire-Derived Aggregate (TDA). Of particular interest is the use of TDA with a maximum particle size of 300 mm or 12 inches (Type B). Type B TDA requires less processing and is more economical than TDA with a maximum particle size of 76 mm or 3 inches (Type A). Both Type A and Type B TDA have similar beneficial characteristics such as high hydraulic conductivity, light weight and strong durability. However due to the size difference, Type A is easier to install in projects with more confined spaces (gas trenches and infiltration galleries) and Type B is easier to use in projects with larger spaces (landslide repair, retaining walls). In conjunction with CalRecycle, researchers at the University of California at San Diego (UCSD) have quantified the shearing properties of Type B TDA in both monotonic and cyclic loading situations, the shearing behavior of Type B TDA with different interface materials, and the pullout behavior of geosynthetic reinforcements embedded in Type B TDA. The results of these studies have been useful in designing geosynthetic-reinforced retaining walls constructed from Type B TDA, including the Ortega Ridge project constructed near Montecito, California in 2019.

Further research is needed on the behavior of Type B TDA in different loading scenarios where the combined compression and shearing behavior (bearing capacity) of TDA and the TDA-structure need to be considered. A specific application for this research would be shallow foundations constructed on Type B TDA to support vertical or inclined loads. A landslide repair or retaining wall with TDA backfill could use this research to place existing water utility pipelines within the TDA fill rather than relocate them outside of the site. Currently, it is unknown whether bearing capacity and settlement analyses developed for soils can be directly applied to Type B TDA. This study seeks to perform a series of full-scale tests on shallow foundations in Type B TDA and analyze their results using available soil models and parameters obtained from shear strength experiments performed at UCSD.

Research is also needed to characterize the seismic response of TDA fill layers beneath shallow foundations. Due to the high dampening ratio of TDA, a TDA layer beneath a structure may provide seismic isolation and reduce shear stresses to an overlying structure. This research may lead to increased use of TDA in new building construction in areas prone to seismic activity.

II. WORK TO BE PERFORMED

This study shall determine the bearing capacity of settlement of shallow footings constructed in Type B TDA, compare experimental results with predictions from soil-based theories, and provide necessary modifications specific to Type B TDA. The effects of footing dimensions, footing embedment, inclination angle, and footing roughness (precast vs. cast-in-place) will also be studied.

A large-scale laminar container (available at UCSD) shall be used for testing as shown in Figures 1, 2(a) and 2(b). This container has inside dimensions of 2.9m (height), 3.92m (width), and 1.77m (depth), and is formed from a set of stacked steel rings held within a rigid frame. This container is typically used to investigate the seismic response of soil layers in conjunction with the Powell laboratory shaking table at UCSD (Figure 1). For this study, the container and shaking table provides a rigid container suitable for testing TDA Type B layers in plane-strain conditions expected for strip footing-type foundations. The dimensions are suitable to have full-scale footing sizes with minimal boundary effects, so no scaling factors would be needed. The inside surfaces of the container will be lined with two layers of plastic sheeting to reduce friction between the TDA and the side walls of the container. A cast-in-place footing can be simulating by placing a layer of TDA within a form then placing concrete. This footing along with bonded TDA particles can be transferred to the container for testing.

Figure 1: Picture of large-scale laminar container available at UCSD

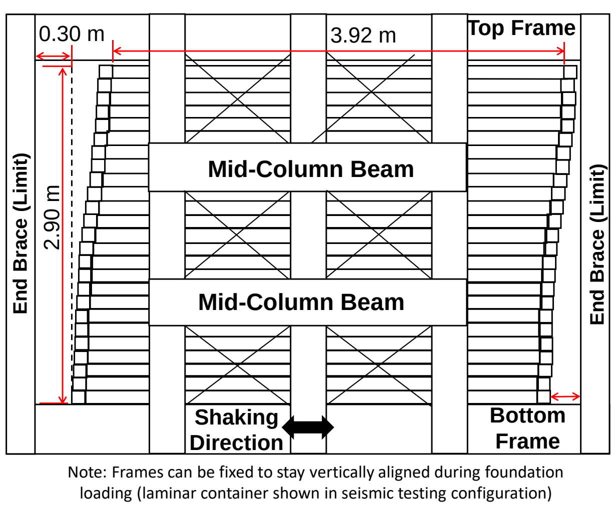

Figure 2a: Schematics of large-scale laminar container available at UCSD

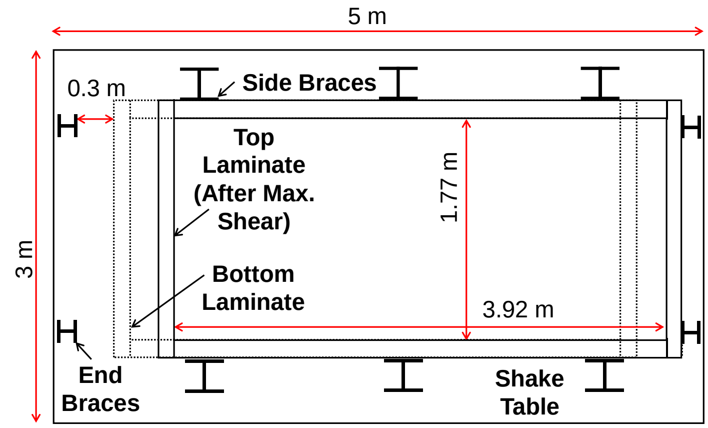

Figure 2b: Schematics of large-scale laminar container available at UCSD

Another advantage of using this laminar container is that an A-frame can be connected to the strongwall of the laboratory (Figure 1) to provide a reaction for hydraulic actuators used to apply forces to footings in the layer of TDA in either vertical or inclined configurations as shown in Figure 3(a). For the inclined loading tests, placement of the footing to the side of the container would permit the development of a passive wedge in the TDA to the right of the footing. For vertical loading tests, placement of the footing will be placed in the center to minimize edge effects. The sizing of the footing will depend on the bulb of stress induced by loading, as shown in Figure 3(b). For a 3m layer of TDA, a footing width of 0.5m would be reasonable for an embedded footing and a footing width of 1.0 m would be reasonable for a surface footing.

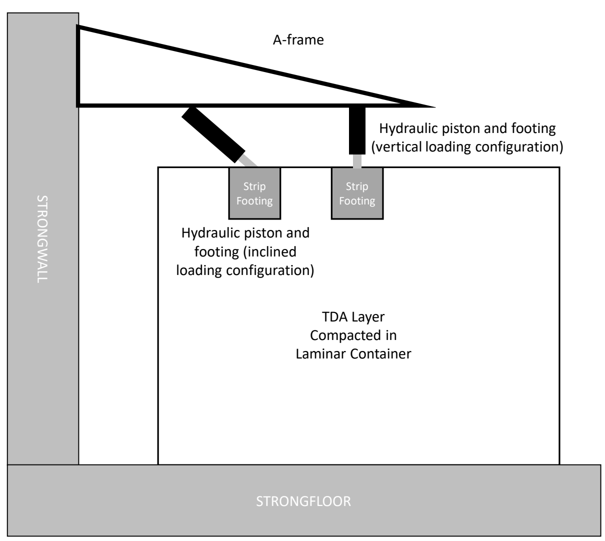

Figure 3a: Testing geometry: Configurations proposed for performing vertical or inclined loading tests on footings.

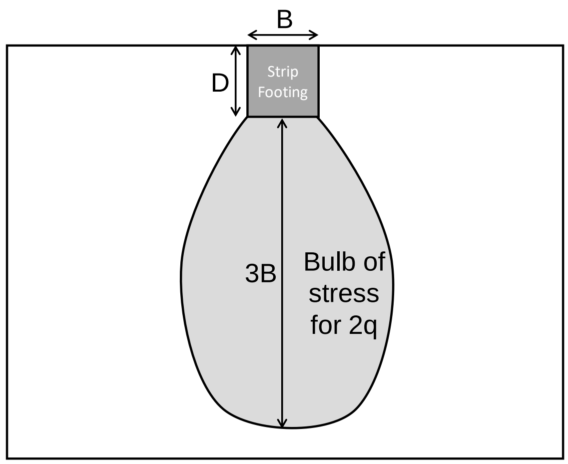

Figure 3b: Testing geometry: Restrictions on footing geometry for appropriate stress distribution in container

A range of instrumentation is available at UCSD, including earth pressure cells, load cells, and potentiometers that will be used, as needed, to evaluate the stress distribution and failure mechanisms encountered during vertical and inclined loading tests (Figures 4(a), 4(b), 5(a), and 5(b)). These instrumentation configurations are suitable to discern surface movements during loading, subsurface deformations, and stress distributions. Tests shall be performed where the footing load is applied using hydraulic actuators at a constant displacement rate (to detect the peak bearing capacity and any postpeak softening), and corresponding settlement.

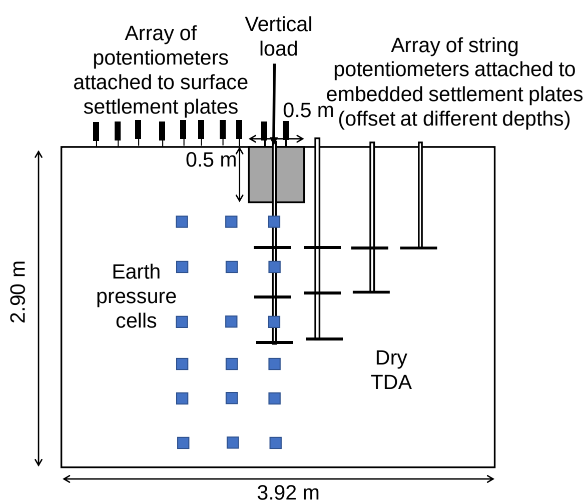

Figure 4a: Example of instrumentation layout for vertical loading of footings: Elevation

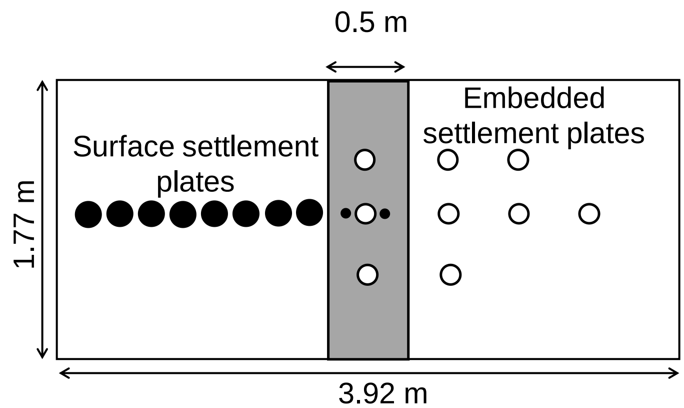

Figure 4b: Example of instrumentation layout for vertical loading of footings: Plan

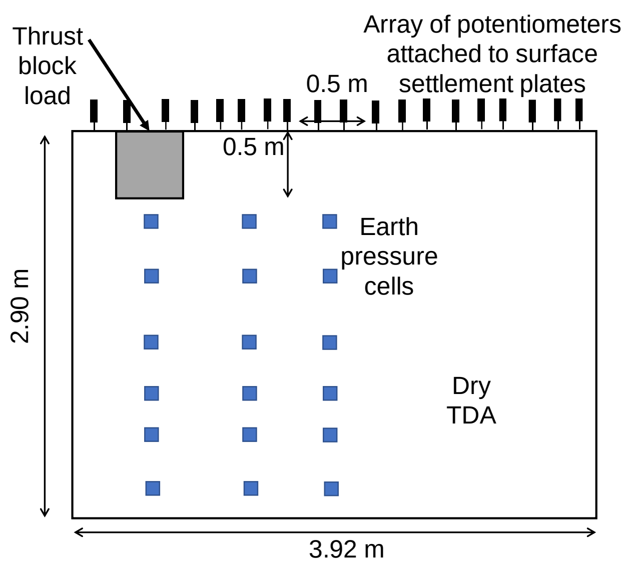

Figure 5a: Example of instrumentation layout for inclined loading of footings: Elevation

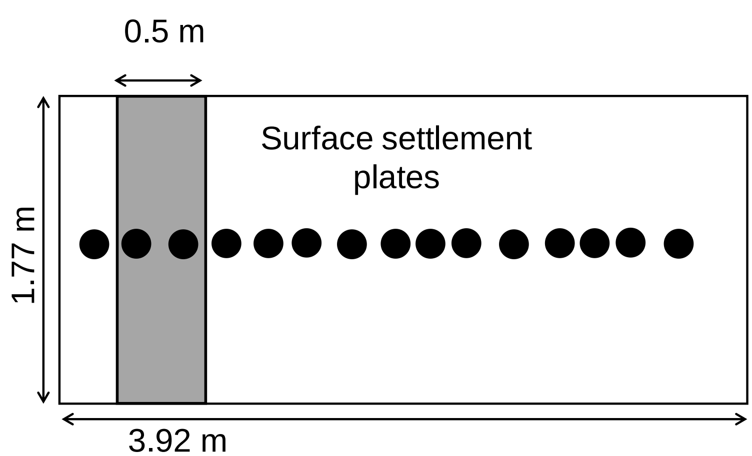

Figure 5b: Example of instrumentation layout for inclined loading of footings: Plan

III. TASKS IDENTIFIED

This contract will consist of the following four tasks:

Task 1: Mobilization of Laminar Container and Footings

Mobilize the large-scale laminar container and assemble the loading frame on the strongwall. Cast four different concrete footings in preparation for testing. Place the Type B TDA shall into pre-weighed bags in preparation for placement and compaction.

Task 2: Experimental Program

Place the TDA specimen inside the box in lifts, along with the footing and sensors at the target locations. Compact the TDA using a plate compactor and ensure that all TDA layers have the same compaction conditions. At the end of each task, the TDA shall be removed and then replaced as footing loading may lead to permanent deformations. The variables for the experimental program will involve:

- TDA material: Type B
- Test types: Vertical footing loading, inclined footing loading, seismic
- Footing Width: 0.5 m, 1.0 m
- Footing Embedment: 0 m, 0.5 m
- Footing surfaces: Precast (smooth), cast-in-place (rough)

Table 1 shows a summary of the testing program: 6 vertical loading tests, 2 inclined loading tests, and 3 seismic tests (total of 11 tests). Each test shall be conducted until reaching a vertical displacement of 1B or a clear post-peak bearing capacity value. The seismic tests will involve application of realistic seismic motions representative of different regions of California.

Table 1. Summary of the testing program

Task/Test Type	Test No.	Test Parameters (displacement rate of 10 mm/min)
2A. Vertical Loading	2A-1V	Precast footing, B= 0.5 m, D= 0m
2A. Vertical Loading	2A-2V	Precast footing, B= 0.5 m, D= 0.5 m
2A. Vertical Loading	2A-3V	Cast-in-place footing, B= 0.5 m, D= 0.5 m
2A. Vertical Loading	2A-4V	Cast-in-place footing, B= 0.5 m, D= 0m
2A. Vertical Loading	2A-5V	Precast footing, B= 1.0 m, D= 0 m
2A. Vertical Loading	2A-6V	Cast-in-place footing, B= 1.0 m, D= 0 m
2B. Inclined Loading	2B-1I	Footing TBD, B=0.5 m, D=0.5 m, inclination angle of 45 degrees
2B. Inclined Loading	2B-2I	Footing TBD, B=0.5 m, D=0.5 m, inclination angle of 30 degrees
2C. Seismic Loading	2C-1S	Footing TBD, B=0.5 m, D=0.5 m, TDA Thickness of 1 m
2C. Seismic Loading	2C-2S	Footing TBD, B=0.5 m, D=0.5 m, TDA Thickness of 2 m
2C. Seismic Loading	2C-3S	Footing TBD, B=0.5 m, D=0.5 m, TDA Thickness of 3 m

Task 3: Data Analysis

Raw data from Task 2 will consist of stress vs. displacement for each test specimen, along with the time series of settlement or earth pressure from the different sensors. The stress vs. displacement curves will be used to determine the bearing capacity of TDA Type B.

The bearing capacity values shall be compared with various theories available in the literature (Terzaghi, Brinch-Hansen, Vesic). Bearing capacity factors shall be adjusted for TDA based on analysis. For seismic tests, the modulus reduction properties from available literature (McCartney) will be used.

Task 4: Final Report

Contractor shall prepare and submit a Draft Final Report to the CalRecycle's Contract Manager for review by May 30, 2022. The Contract Manager will provide written approvals or requests for changes or revisions to the Contractor. The Contractor shall incorporate any changes or revisions required by the Contract Manager and submit a Final Report. The report shall include the following: a description of the testing setup and instrumentation plans, test procedures, test data summary and analyses, and conclusions regarding the performance of shallow footings on Type B TDA as well as recommendations for future TDA research. Final reports are subject to the Special Terms and Conditions of this contract (Exhibit D.1).

IV. CONTRACT/TASK TIME FRAME

The work under this contract will take approximately 24 months. Assuming a May 1, 2020 start date, the due dates for each task are given below, with some tasks being performed concurrently. These due dates may need to be adjusted, pending actual contract start date.

Table 2. Project Work Schedule

Task	Due Dates*
Task 1 – Mobilization of container for testing	August 30, 2020
Task 2 – Experimental Program	
Task 2A – Vertical Tests	January 30, 2020
Task 2B – Inclined Tests	March 15, 2021
Task 2C – Seismic Tests	August 30, 2021
Task 3 – Data Analysis	February 30, 2022
Task 4 – Final Report	March 30, 2022