Explosive Channeling In Submerged Soils

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LONG-TERM GOALS

The goal of this task is to develop a methodology by which the geometry of a channel in the surf zone as produced by a line of explosive charges may be predicted. To achieve this goal, an NRL incompressible hydrocode is required which models the excavation by bubble expansion. If necessary, the initial conditions produced by shock wave effects could be provided by a compressible code. This incompressible code would then be developed and applied, in combination with the results of small-scale tests conducted by the University of Maryland and some larger scale tests, which would then validate and provide an empirical basis for a predictive methodology. The predictive methodology is being developed by NSWC/IND.

OBJECTIVES

The small-scale explosive experiments conducted at the University of Maryland were designed to fulfill the following objectives:

1. Determine the effects of the depth of burial of the charge, the height of water above the soil, and the soil properties (i.e., sand gradation, soil type, and amount of fines and clays) on explosive crater sizes.
2. Shed light on the mechanisms involved in cratering under water.
3. Provide a database for validating the incompressible hydrocode being developed by the Naval Research Laboratory.
4. Provide a database of small-scale craters that can be used in developing a predictive methodology.

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APPROACH

Small-scale explosive experiments were conducted at 1-g and under high gravitational levels in the geotechnical centrifuge. Since the soil behavior is highly nonlinear and stress dependent, the geotechnical centrifuge provides a means for creating stress fields in the small models under high gravity levels similar to those that are present in a full-scale prototype. Comparison of the results of the tests conducted at 1-g and those conducted in the geotechnical centrifuge provides a means of evaluating the importance of the soil stress as well as determining the appropriate scaling laws to be used for interpreting the results of the small-scale models.

To shed light on the mechanisms involved in the process of cratering under water, a soil coloring scheme was employed to determine the apparent and true craters, and therefore, evaluate the importance of post-explosive events such as wash back, erosion, and water waves in different types of soils. Additionally, two-dimensional tests are being conducted in a transparent box in conjunction with high-speed photography to study and quantify those processes.

In this phase of the projects, single charges are used to produce single craters. The effects of different parameters on the resulting craters are studied. In the next phase, multiple charges will be used to crate continuous channels.

WORK COMPLETED

A total of 83 small-scale model tests were conducted in three different soils: fine uniform silica sand (FS); coarse well-graded silica sand (CS); and clayey sand (UK soil). Description of the test series and the conditions investigated are as follows:

Soil Types:

1. Fine Uniform Silica Sand (FS)
2. Coarse Well-graded Silica Sand (CS)
3. Clayey Sand from Weston Super Mare (UK)

Notes: (1) DOB is depth of burial of charge
(2) LOW is level of water above soil

<u>One g Tests</u>:

In Saturated Soil:

8 tests in CS	-2.5 cm to 7.5 cm DOB
6 tests in FS	-2.5 cm to 7.5 cm DOB
6 tests in UK	-2.5 cm to 5.0 cm DOB

Submerged Tests:

8 tests in FS	Different DOB's and Different LOW to simulate tests at Port Wakefield
3 tests in FS	With color markers to determine wash back extent 0 DOB, 4.4 CM LOW

Black Powder Tests:

6 tests in dry, saturated, and submerged soils with charges of black powder.

High g Tests:

In Dry Soil:

8 tests in FS	0 DOB at G levels from 1 to 80 g

In Saturated Soil:

7 tests in FS	0 DOB at G levels from 5 to 80 g
5 tests in FS	2.5 cm DOB at G levels from 10 to 80 g
4 tests in FS	5.0 cm DOB at G levels from 10 to 80 g

Submerged Tests:

4 tests in UK	0 DOB with 4.4 cm LOW at G levels from 10 to 80 g
4 tests in UK	2.5 cm DOB with 4.4 cm LOW at G levels from 10 to 80 g
8 tests in UK & FS	2 different DOB (0 & 2.5 cm) & LOW (1.2 & 4.4 cm) at G level of 26 g
2 tests in UK & FS	DOB (2.2 cm) and LOW (1.2 cm) at G level of 81 g

Modeling of Models:

4 tests in FS in saturated and submerged condition to conduct modeling of models investigation @ 0 DOB

RESULTS

The craters created by explosives in both saturated and submerged soils are sensitive to the depth of burial of the explosive, the height of water above the soil, gradation of the soil, as well as the amount of fines (silt and clay) present in the soil. In saturated soils, the largest craters are produced at a positive optimum depth of burial, similar to dry soils. On the contrary, the largest craters in submerged soils are produced at negative depth of burial (charge above the soil) and surface charges. The presence of water above the soil produces surface waves and wash back processes which reduce the size of the apparent craters compared to the true craters. The amount of wash back depends heavily on the type of soil and the amount of fines present in the soil. In clean sands, wash back is very significant and the resulting apparent craters are significantly shallower than the true craters. The effect of wash back processes in clayey soils is minor and the size of the apparent craters is close to the true craters. Larger craters were observed in saturated fine sands than in coarse sands. This effect is attributed to the larger negative pore water pressures in the fine sands, which give the soil higher strength and the crater sides greater stability.

Modeling of models in the geotechnical centrifuge verified the applicability of the scaling laws developed by Schmidt and Holsapple (1980) for explosive cratering in dry sands to cratering in both saturated and submerged sands. The value of the exponent (n), a material property, which reflects the explosive cratering yield in soil materials was shown to be lower in both saturated and submerged soils than in dry soils. Experimental results also showed that the value of this exponent decreases dramatically with increasing the depth of burial of the explosive.

Some tests were conducted with black powder in an effort to examine the cratering phenomen without the shock produced by conventional high explosives. Preliminary results indicate that the craters created by black powder explosives were much smaller than those created by the high explosives used.

IMPACT/APPLICATIONS

The results of the small-scale explosive experiments in saturated and submerged soils showed the importance of the site-specific properties when explosive cratering or channeling is used under water. Smaller craters are expected on clean sandy beaches compared to clayey and organic material deposits encountered at other beaches. Hence, larger amount of explosives is required to create channels of specific size on clean beaches.

The test results also showed the importance of post-explosive processes, i.e., wash back and erosion. Understanding these processes and incorporating them in the incompressible hydrocode being developed is essential for precise prediction of channel size.

TRANSITIONS

The work done under this task provides the foundation for the analytic and computational work being done under a related task by the Naval Surface Warfare Center, Indian Head Division (NSWC/IHD) and the Naval Research Laboratory (NRL), respectively. Thus, the transition directly is to NSWC/IHD and NRL. Through them, it will provide the basis for operational forces to determine how to use channeling to breach mine and obstacle fields.

RELATED PROJECTS

Channeling tasks at NRL and NSWC/IHD - N0001498WX30162

REFERENCES

R.M. Schmidt and K.A. Holsapple, 1980: “Theory and experiments on centrifuge cratering”, *Journal of Geophysical Research*, 85(B1), pp. 235-252.

PUBLICATIONS

Fourney, W.L., Randles, R., and Dick, R.D., 1997: “Displacement of Sand and Obstacles Under Standing Water with Explosives”, *FRAGBLAST, The International Journal for Blasting and Fragmentation*, Vol. 1, pp. 393-416.