13 Mar 1991, 1:30 pm - 3:30 pm

A Study of Blast Pressure from Underwater Borehole Blasting

T. S. Thandavamoorthy
Structural Engineering Research Centre, Madras, India

Proceedings: Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, March 11-15, 1991, St. Louis, Missouri, Paper No. 11.35

A Study of Blast Pressure from Underwater Borehole Blasting

T.S. Thandavamoorthy
Assistant Director, Structural Engineering Research Centre, Madras, India

SYNOPSIS: The paper presents an experimental study conducted under laboratory conditions on the measurement of the pressure waves transmitted into water that are radiated from following the detonation of an explosive charge buried in a block. In order to simulate full scale blasting operations at sea, small explosive charge of 1.8g PETN was buried in a concrete block and detonated under water. Information concerning the test set-up, instrumentation, type of explosives used, scaling factor and measurement of pressure is briefly described. The paper also presents analysis of the test results in the form of FFT's and Transfer functions and details of its importance to practical blasting operations at sea using buried explosive charges.

INTRODUCTION

Underwater borehole blasting in hydrotechnical construction practice, for example, dredging operations with pressure charges, destruction of underwater structures etc. has now become a common practice. Under these circumstances, the shock wave radiated from the buried charge, transmitted in water and impinging on the structures in the vicinity may set the structure under vibration. In order to calculate the amplitude of vibration of the structure and to work out the safe distance from the charge magnitude of the shock pressure and its spectral characteristics are required.

At present whatever information available on the propagation of pressure waves is mostly related to the explosion of freely suspended charge underwater and its radiation in fluid medium or the detonation of charge buried in elastic half-space and its radiation in the solid medium. Much work was concerned with the explosive charges freely suspended in water. Cole (1948) and Kim and Binder (1965) have shown that the shock pressure emanating from a charge freely suspended in water is characterised by a very sharp rise to a peak value followed by a rapid decay. Bjorno and Levin (1976) have taken measurements of pressure waves underwater at a short range from the detonation of small amounts of chemical explosives. Gaspin et al (1972) have presented pressure-time records from underwater detonations of 35.60-, 213.60-, and 4450-N(8-, 48-, and 1000-lb) explosive charges. Poche (1972) has reported the measurements of shock wave peak pressure underwater produced by exploding small (0.133N/13.5 gr) detonators at ranges from 0.3 to 27m (1 to 90 ft).

As regards the shock wave arising in the bedrock, Hisatake et al (1983) and Valliappan and Ang (1988) have also stated that the shock pressure emanating from an explosive charge buried in rock is characterised by an increase to a peak pressure and followed by an exponential decay of it. Morris (1974) has presented an experimental program conducted to measure the peak pressures produced at the ground surface by the detonation of shallow buried explosive charges. Schmidt (1975) has presented pressure data from measurements using 1/100 scale models as a result of an investigation of underground explosion.

As regards the coupled problem of the radiation into water from a charge detonated in underlying bedrock, Gil'manov (1984) has conducted experimental investigation to study the formation of a water shock wave from underwater borehole blasting, but his work was mainly related to estimating the safe distance for the safety of ichthyofauna. There is no other information available regarding the characteristics of the formation and propagation of shock waves due to underwater borehole blasting. This aspect is of great importance, since most of the other factors controlling the propagation and effects of shock waves, such as the safety of underwater structures are well understood. With this objective in mind a laboratory experiment was carried out for the first time to measure the shock pressure underwater and its spectrum due to the detonation of a buried charge.

EXPERIMENTAL PROCEDURE

The experiments were conducted in AB Wood Laboratory of the Institute of Sound and Vibration Research, University of Southampton. This experiment conducted relates to the measurement of blast pressure underwater due to the detonation of a 1/10 scaled high explosive charge of different delay both freely suspended under water and also buried in a 1/10 scaled model of a submerged concrete block under laboratory conditions. The scaling factor for laboratory condition of test was selected based upon the principle of similarity. A scaling factor of 10 was selected in this test. The explosive used in the experiments was an ICI medium strength detonator with a 1.8 g charge of PETN. No.2 and 5 delay detonators were used in this experiment. The shape of the charge was cylindrical with a diameter of 8 mm and a length of 80 mm. Two types of tests were conducted. First the scaled high explosive charge with No.2 and 5 delay was suspended freely in water. A total of 17 tests were conducted in this category to verify statistically the similarity of the shock wave profile and to create a data base. In the second test the charge was buried in a submerged concrete block. The main object of burying the charge in the concrete block was to study the reduction in the intensity of the water shock wave due to burial of the charge. In this category two types of boreholes were used. One 10mm diameter and 78mm deep hole and the other 20mm diameter and 90mm depth of hole. The aim of this exercise was to study the effect of bad blasting practice. A total of three tests in each category of hole size were performed at different times. The test set up and the associated instumentation are shown in Fig.1.

The instrumentation used in this experiment consisted of a piezoelectric hydrophone with a natural frequency of 150kHz., a capacitor pad to bring the sensitivity of the output of the hydrophone within the input range of the transient capture and a computer. The explosives were fired by means of a blasting machine. The pressure wave in the water resulting from the detonation of explosive was digitally recorded using the spherical piezoelectric hydrophone and analyzed using a proprietory software. In the first category of test first one hydrophone situated at 0.5m from the charge was employed to measure the shock pressure. In the second case, two hydrophones, at 0.5m and the other at 1m from the charge were used to measure the resulting shock pressure. The measurement at 1m was used primarily to check the scaling law for the detonators used in the test. More details of the experimental procedure are given elsewhere (Thandavamoorthy,1990a).

PRESENTATION OF RESPONSE SPECTRA, TRANSFER FUNCTIONS AND DISCUSSION

The measured pressure-time histories of freely suspended charges and buried charges were given in detail in other papers of the writer. (Thandavamoorthy 1990a, Thandavamoorthy 1990b). A typical pressure-time history for a freely suspended charge is shown in Fig. 2. As a measure of the repeatability of the results, Fig. 3 illustrates several of the recordings made, overlaid on the same scale. It may be seen that there is a good repeatability of results. Following a rapid initial rise to a peak pressure of the order of 7MPa, there is a rapid decay of pressure. The duration of the initial peak is of the order of 0.3ms. It should be cautioned, however, that the time history presented does not fully represent the actual pressure wave arising in the water since the natural response of the hydrophone is of similar order to the duration of the recorded wave. In the context of this paper, however, where the results are presented finally as Transfer Functions relating the spectrum of a buried charge to that of a freely suspended charge, this is of secondary importance since the effect is superimposed equally on all measurements and are cancelled when estimating the Transfer Function. A typical pressure-time history of a buried charge is shown in Fig.4. The reduction in the level of peak pressure due to burial of charge is illustrated in Fig.5.

Figure 6 illustrates a typical FFT of the 8ms pressure-time history of a freely suspended charge. The ordinate is the pressure spectral level in dB i.e., 1Pa per Hz. and the abscissa is the frequency on a logarithmic scale. It may be seen that the spectrum of the pressure-time history for the freely suspended charge is broad and flat, with little change in level occurring within the frequency range of interest. As is expected from the repeatable time histories, the spectra are reasonably repeatable with little variation occurring in their mean levels. Some degree of oscillation about a mean level occurs; it is suggested that this is due to the interference of spectrum of reflections with that of the direct arrival.

The typical response spectrum of 8ms pressure-time history of a buried charge is shown in Fig.7. In this case also the ordinate represents the pressure spectral level in dB., 1Pa per Hz. and the abscissa is the frequency on a logarithmic scale. Here also the spectrum is broad and flat. There is considerable change in level within the frequency range of interest.
The average spectra of several of the pressure-time recordings both for freely suspended charge and for buried charge were computed. An overlay of average spectra of freely suspended charges and buried charges is given in Fig.8. This figure illustrates quite clearly the repeatability of the spectra of buried charges and also the substantial reduction in the peak level of the pressure due to burial of charges.

From the average spectra of free and buried charges, the Transfer Functions were computed dividing the average spectra of buried charge by that of the free charge. Figure 9 illustrates an overlay of the transfer functions of buried charges in small-hole and big-hole cases. This is quite clear from Fig.9 that the transfer functions of these two cases are similar and also repeatable. The apparent shift in the frequency is due to some problems in the plotting routine of the proprietory software.

CONCLUSIONS

From the above study, the following conclusions can be drawn:

(1) The pressure wave from buried charges is reduced substantially from that occurring for freely suspended charges. The implication of this statement is that for buried charges a substantially larger charge size is allowable for a given damage level than would be the case for a freely suspended charge. Safe stand off distances and charge sizes calculated by means of parameters based on measurements performed on a freely suspended charges will be very conservative.

(2) The reduction in the level of peak pressure due to burial of charge is of the order of 12 over that of free charge.

(3) The spectral level of burial of charge is reduced by 9 to 12 dB over that of free charge.

(4) Too large a hole compared to the size of

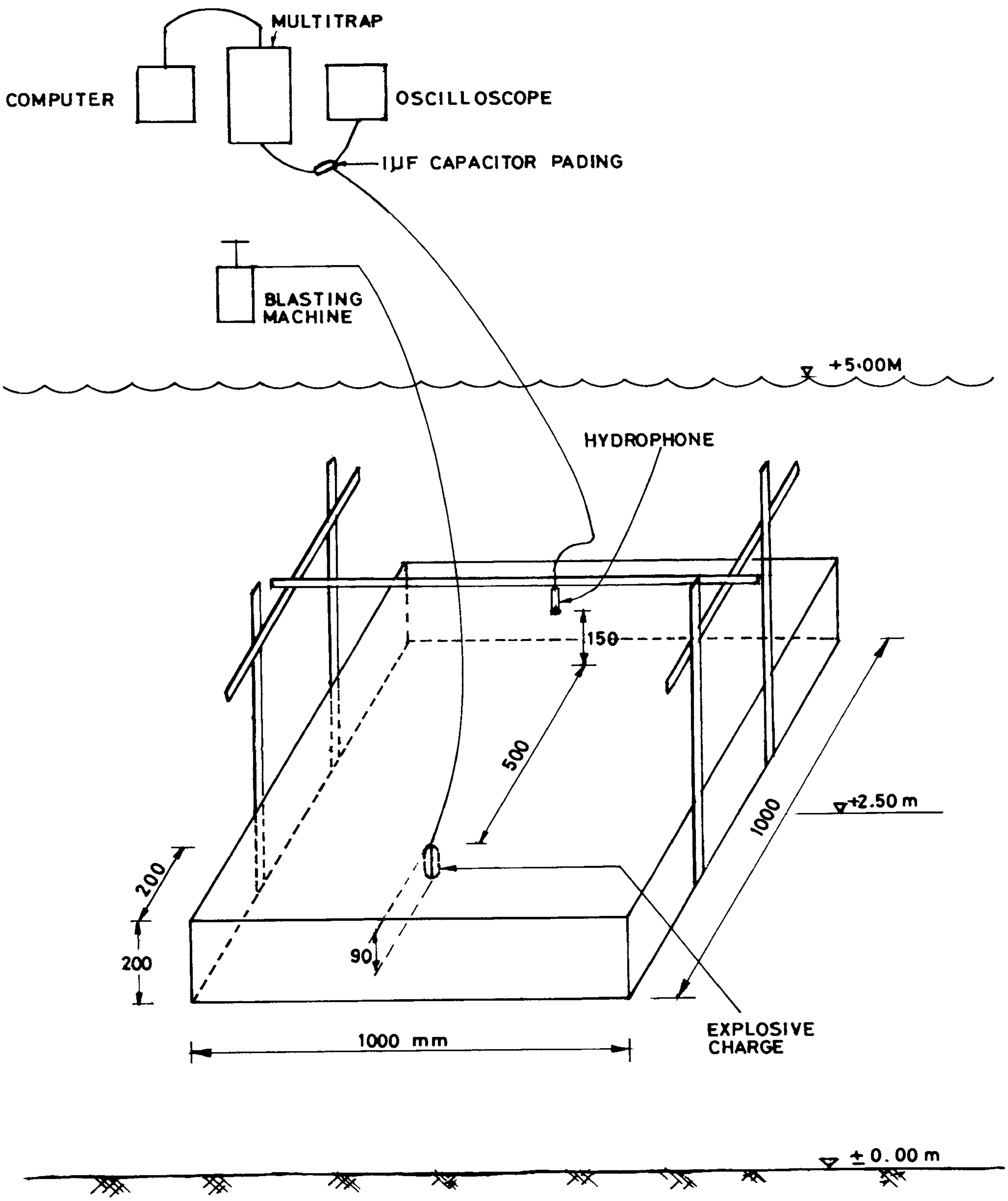

FIG.1 TEST SET UP FOR BLASTING AND THE INSTRUMENTATION

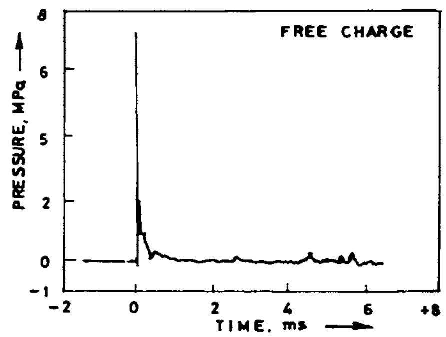

FIG.2

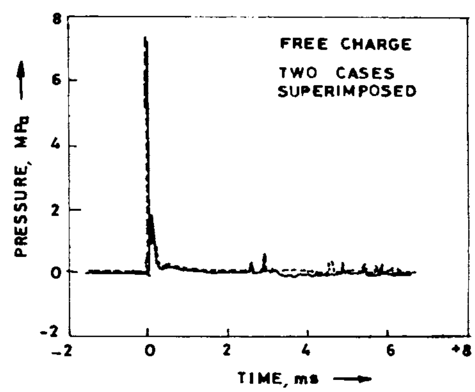

FIG.3

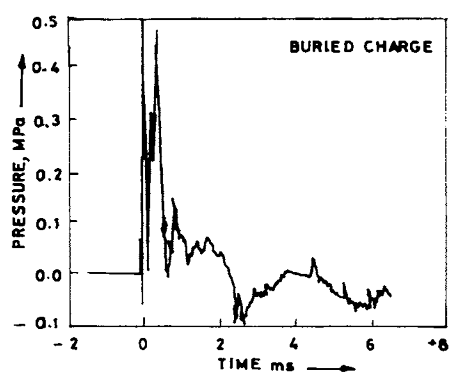

FIG.4

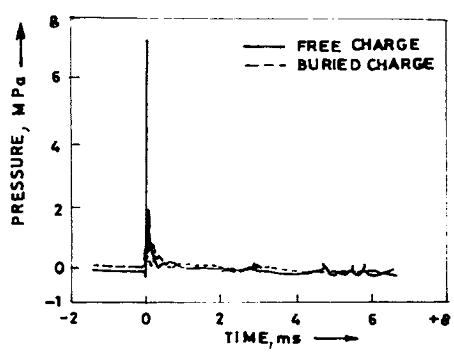

FIG.5

PRESSURE—TIME HISTORY

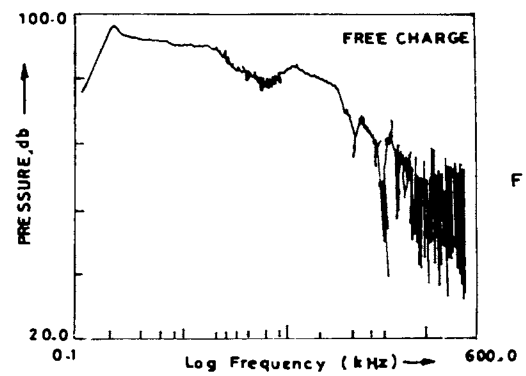

FIG.6

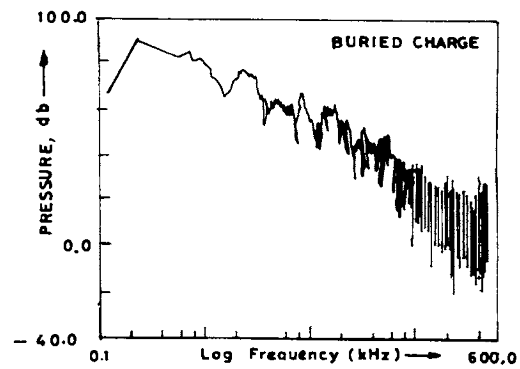

FIG.7

RESPONSE SPECTRUM

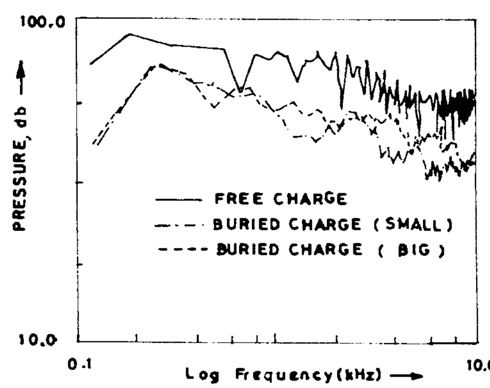

FIG.8

AVERAGE FFTs

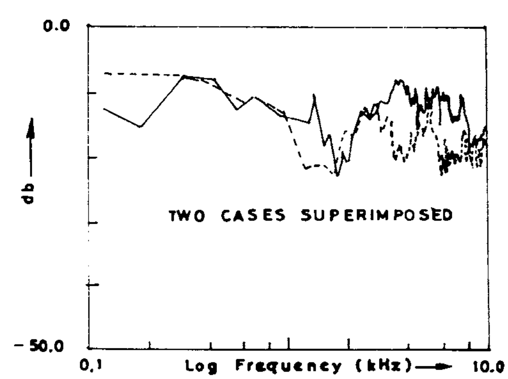

FIG.9

TRANSFER FUNCTION

the charge constitute a bad blasting practice.

It is suggested that further experiments need to be conducted by varying the distance of the hydrophone from the charge and also increasing the depth of burial of charge before any concrete recommendations can be made.

ACKNOWLEDGEMENTS

The experimental work was carried out at the Institute of Sound and Vibration Research, University of Southampton, UK, during the deputation of the writer under British Council fellowship. The writer wishes to express his gratitude to the Director, Structural Engineering Research Centre, Madras, for permitting him to publish this paper.

REFERENCES

Bjorno, L., and Levin, P.,(1976), "Underwater Explosion Research Using Small Amounts of Chemical Explosives, "Ultrasonics, Vol.14, No.6, Nov., pp. 263-367, Shock Vib. Dig., Vol.9, No.4, Apr. 1977, Abs. No. 77-735, Eng. Ind. Annu., Vol. 76, 1977, Abs. No. 030728.

Cole, Robert H., (1948), "Underwater Explosions", Princeton Univ. Press, Princeton, New Jersey.

Gaspin, J.B., Goertner, J.A., and Blatstein, I.M.,(1972), "The Determination of Acoustic Source Levels for Shallow Underwater Explosions," J. Acoust. Soc. Amer, Vol.66, No.5, Nov., pp 1453-1462, Shock Vib Dig. Vol.12, No.4, Apr. 1980, Abs. No. 80-873, Eng. Ind. Annu., Vol.79, 1980, Abs. No. 032483.

Gil'manov, R.A., (1984), "Effect of Shock Waves During Underwater Borehole Blasting," Hydrotechnical Construction, Vol. 18, No. 5, May, pp. 221-225.

Hisatake, M., Sakurai, S., Ito, T., and Kobayashi, Y.,(1983), "Analytical Contribution to Tunnel Behaviour By Blasting," 5th Intl. Cong. on Rock Mech., ISRM, Melbourne, Vol. 2, pp. E191-194.

Kim, Y.C., and Binder, R.C., (1965), "Response of Models to Water-Shock Loadings," J. Eng. Mech. Divn., ASCE, Vol. 91, No. EM6, pp. 67-89.

Morris, B.L., (1974), "Measurement of Peak Pressures Produced at the Ground Surface by Shallow Buried Explosives," Shock Vib. Bull., No. 44, Pt. 3, Aug., pp. 203-212, Shock Vib. Dig., Vol. 7, No. 3, Mar. 1975, Abs. No. 75-467.

Poche, Jr., L.B., (1972), "Underwater Shock Wave Pressures from Small Detonators," J. Acoust. Soc. Amer., Vol. 51, No. 5, May, pp. 1733-1737, Shock and Vib. Dig., Vol. 4, No. 8, Aug. 1972, Abs. 72-1257.

Schmidt, K.G., (1975), "Investigation of Underground Explosion with Model Tests. Preliminary Report 1," Norwegian Def. Res. Estt., Kjeller, Rept., No. NDRE-VM-182, Mar., 38 pp., Shock Vib. Dig., Vol. 8, No. 2, Feb. 1976, Abs. No. 76-237.

Thandavamoorthy, T.S., (1990a), "Laboratory Measurement of the Blast Pressure underwater due to the underwater Detonation of a Buried Charge", paper under publication.

Thandavamoorthy, T.S., (1990 b), "Blast Pressure from a Buried Charge underwater", Proceedings of International Conference on Advances in Structural Testing, Analysis and Design, Bangalore, India, Vol.II, pp.783-788.

Valliappan, S., and Ang, K.K.,(1988), "Finite Element Analysis of Vibrations Induced by Propagating Waves Generated by Tunnel Blasting," Rock Mech. and Rock Eng., Vol. 21, pp. 53-78.