# PROVIDING AN EARTHQUAKE-LIKE ENVIRONMENT FOR TESTING FULL-SCALE STRUCTURES BY USING THE GROUND MOTION FROM UNDERGROUND NUCLEAR TESTS[I]

by

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## SYNOPSIS

Close-in ground motions from underground nuclear explosives (UNEs) are compared with those from strong earthquakes (EQs). UNE ground motions are considered typical for yields of approximately 10 and 200 kt (kilotons) explosives. It is shown that (1) the peak g-levels of the strongest EQs can easily be duplicated or exceeded (if desired) by UNEs, (2) the response spectra from UNEs are similar to those from EQs, and (3) the duration of strong motion and number of near-peak g-level cycles of UNE ground motion is within the range established by strong EQs. It is concluded that ground motion from UNEs can produce a sufficiently EQ-like environment for testing full-scale structures.

## INTRODUCTION

For years recognized authorities in the seismic field have suggested using ground motions provided by underground nuclear explosions at the US-AEC's Nevada Test Site for testing of large-scale structures. There are several major advantages of using ground motion produced by UNEs: (1) no limit on size or type of test structure, (2) the ground motion is available free as a by-product from nuclear tests, (3) true soil-structure interaction would be achieved, and (4) it is possible to subject the test structures to increasing strong motion varying from elastic response to severe damage.

This paper will show that from a structural response viewpoint typical UNEs generate close-in ground motion similar to that of a possible future strong EQ. Therefore, by predetermining the yield and location of the UNEs (relative to test structures) a test structure can be subjected to ground motion comparable to that of a future strong EQ.

However, to make comprehensive studies and to possibly consider non-linear (i.e. yielding) behavior of structures it may be necessary to generate UNE ground motion with longer pulse durations and also more cycles of near-peak g-levels. This can be accomplished by sequentially firing UNEs or by subjecting test structures to UNE ground motion over longer time intervals (e.g. hours, days, or weeks). Both of these possibilities require further study beyond the scope of this paper.

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## GROUND MOTION COMPARISONS

Three types of ground motion characterizations are included for comparison. These are peak g-level, response spectrum and time-history. For UNEs these quantities depend on explosive yield, depth-of-burial, range (distance from the explosion), geology around the explosive and geology through which the ground shock wave is transmitted.[1] But since most UNEs for a given yield are usually buried in similar geologies and at similar depths it becomes meaningful to consider general curves of peak g-level, response spectra and time-histories versus yield and range.

For ranges less than one depth-of-burial to several depths-of-burial (depending upon the geology around the explosive) the ground motion is such that the top several hundred feet of earth spalls away from the lower layers, often causing a larger peak g-level when the spall gap closes. It would be undesirable to locate test structures within this regime.

The UNE ground motion data presented are for explosive yields of approximately 10 and 200 kts. These values were chosen because they cover the range of yields most frequently detonated.[2] Three stations (A,B,C) are used for each yield. These were chosen because within the availability of measured data these stations are at ranges just at the edge but within the spall zone, just out of the spall zone, and well out of the spall zone. See Figure 1 for the location of each station relative to the spall zone. It should be noted that station B for the 200 kt yield case is further out of the spall zone than would be desired for a test structure. The ideal range would be 10000 ft.

Peak g-level. Figure 1 is a plot of peak g-level versus range for 10, 200 and 1000 kt yields. It is clear from Figure 1 that the peak g-levels of the strongest EQs[3] can easily be duplicated or exceeded (if desired) by typical UNE ground motions.

Response Spectra. Figure 2 shows the relative velocity spectra for the El Centro, Taft and San Fernando EQs. Figure 3 gives spectra for yields of approximately 10 and 200 kt at the three ranges defined in Figure 1. All spectra are for 5% viscous damping. A comparison of these figures show that spectra from typical UNE ground motion are similar to those from strong EQs.

For testing purposes it is also important that the lower yield UNEs ($\sim$ 10 kt) provide suitable ground motion since they are the most frequently detonated. A comparison of the spectra for Stations B and C for both the 10 and 200 kt[III] show that the lower yield UNEs are suitable. Furthermore for testing structures in their nonlinear or damage response regime spectra exceeding those generated for El Centro and San Fernando (Pacoima) is

[III] In making this comparison allowance must be made for the fact that Station B for the 200 kt case was located (relatively) much further out from the edge of the spall than Station B of the 10 kt case. See Figure 1.

perhaps desirable. This also can be accomplished with the lower yield UNEs. For example, compare the 10 kt, Station B spectra with the El Centro and San Fernando spectra.

Time-History. Figure 4 gives accelerograms for UNEs with yields of approximately 10 and 200 kt at Station B. The longer time duration of the 200 kt record is in part due to the increase in yield and in part the larger range of Station B for the 200 kt. However in general increasing the yield results in an increase in time duration of the strong motion in the UNE record.

If these UNE accelerograms are compared to EQ accelerograms (Reference 3) it is seen that except for the Parkfield EQ the total time of duration of the strong UNE ground motion is shorter than for the strong EQs. Cloud and Perez[4] suggest that it is the time of duration of the acceleration above some level that is the important parameter instead of the total duration of the record. Figure 5 shows a comparison of the total time the acceleration was above various levels for several UNE stations and the El Centro and Pacoima Dam records. It is seen from this figure that the time of duration of the higher g-levels for UNEs generally fall between the limits established by the EQ records.

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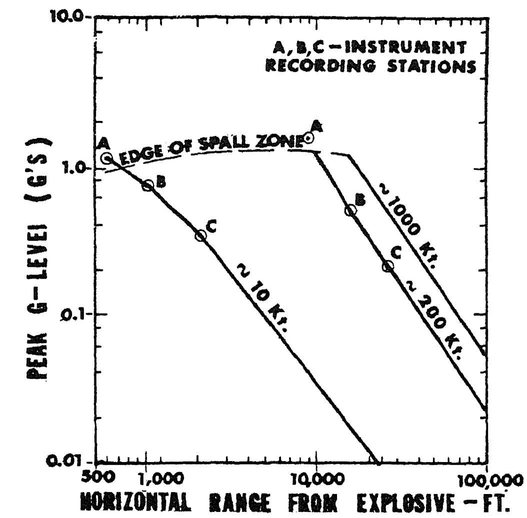


FIG. 1

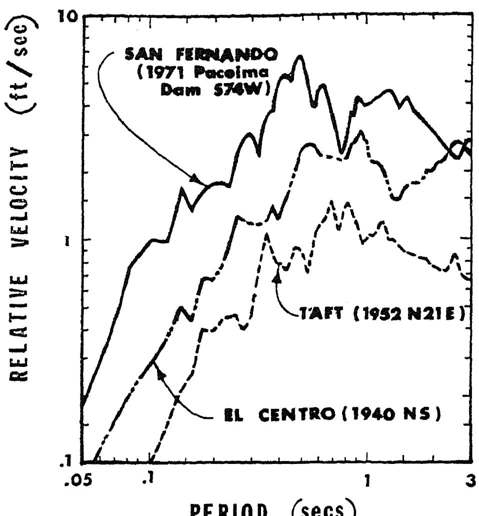


FIG. 2

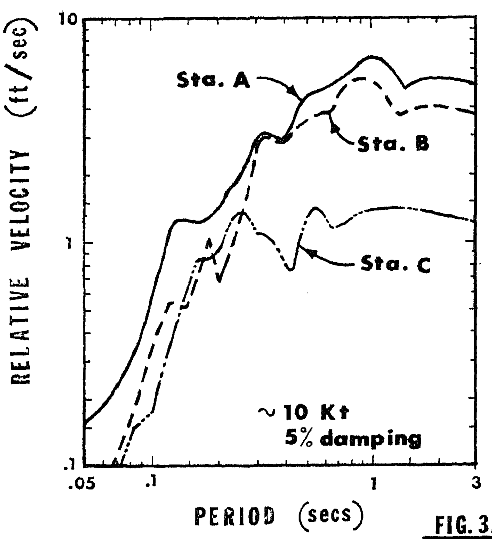


FIG. 3A

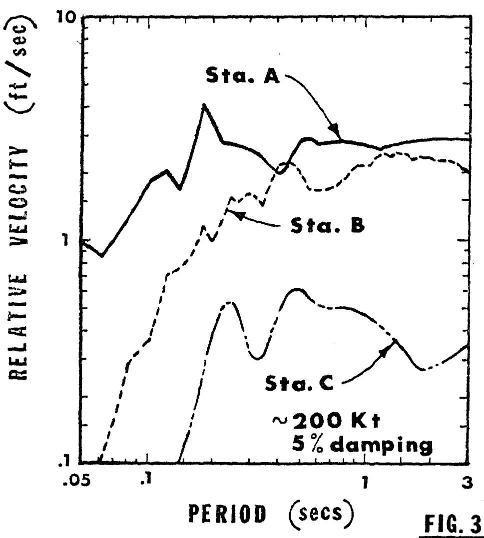


FIG. 3B

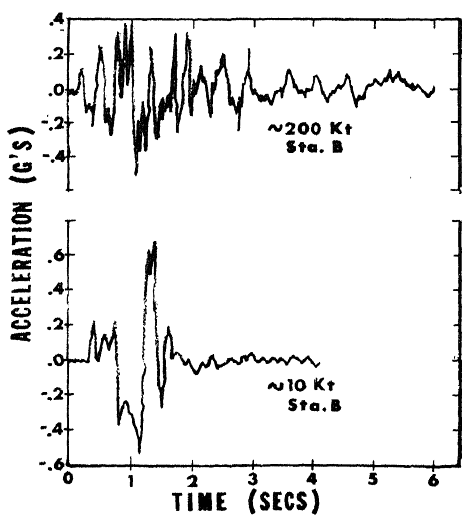


FIG. 4

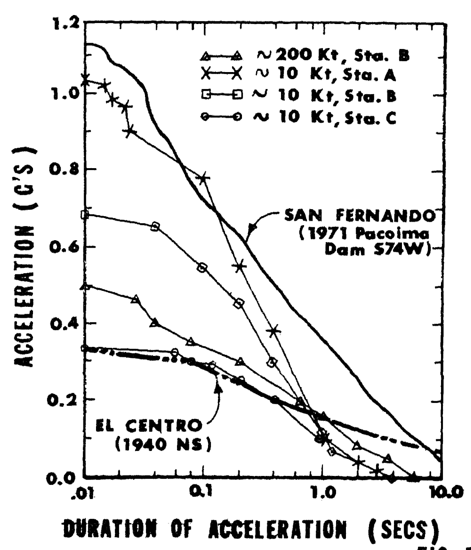


FIG. 5