Southern California Edison Company

P. O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

M. O. MEDFORD
MANAGER, NUCLEAR LICENSING

TELEPHONE
(818) 572-1749

December 20, 1984

Director, Office of Nuclear Reactor Regulation
Attention: J. A. Zwolinski, Chief
Operating Reactors Branch No. 5
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket No. 50-206
Masonry Wall Test Program
San Onofre Nuclear Generating Station
Unit 1

On September 5 and 6, 1984, SCE met with the NRC and its consultants to discuss the results of the masonry wall test program. Following this meeting, additional information was submitted by letter dated October 27, 1984. In a subsequent telephone conversation on November 7, 1984, between the NRC staff and SCE, the NRC staff requested additional information pertaining to the Fuel Storage building walls. The requested information is provided as an enclosure to this letter.

If you have any questions regarding this information, please call me.

Very truly yours,

M. O. Medford

A001
1/1

Question #1:

Document that the walls around the 480V Switchgear Room are the only walls where Section M on Drawing 568140 are applicable.

Response:

The only walls where Section M is applicable are the Fuel Storage building masonry walls FB-5 and the southern 18' portion of wall FB-2 (see Figure 1.1). However, the test walls for the Fuel Storage building represent all the walls above elevation 42', that is, walls FB-1 through FB-7. The bottom connection of all the remaining masonry walls are equal to the connection used in the test program.

Recently, a site inspection was conducted for the "as-built" condition of the walls around the 480V Switchgear Room. The investigation showed that, for all practical purposes, the "as-built" detail above elevation 42' for walls FB-5 and FB-2 is identical to the bottom connection used in the test program. (See response to Question #3).

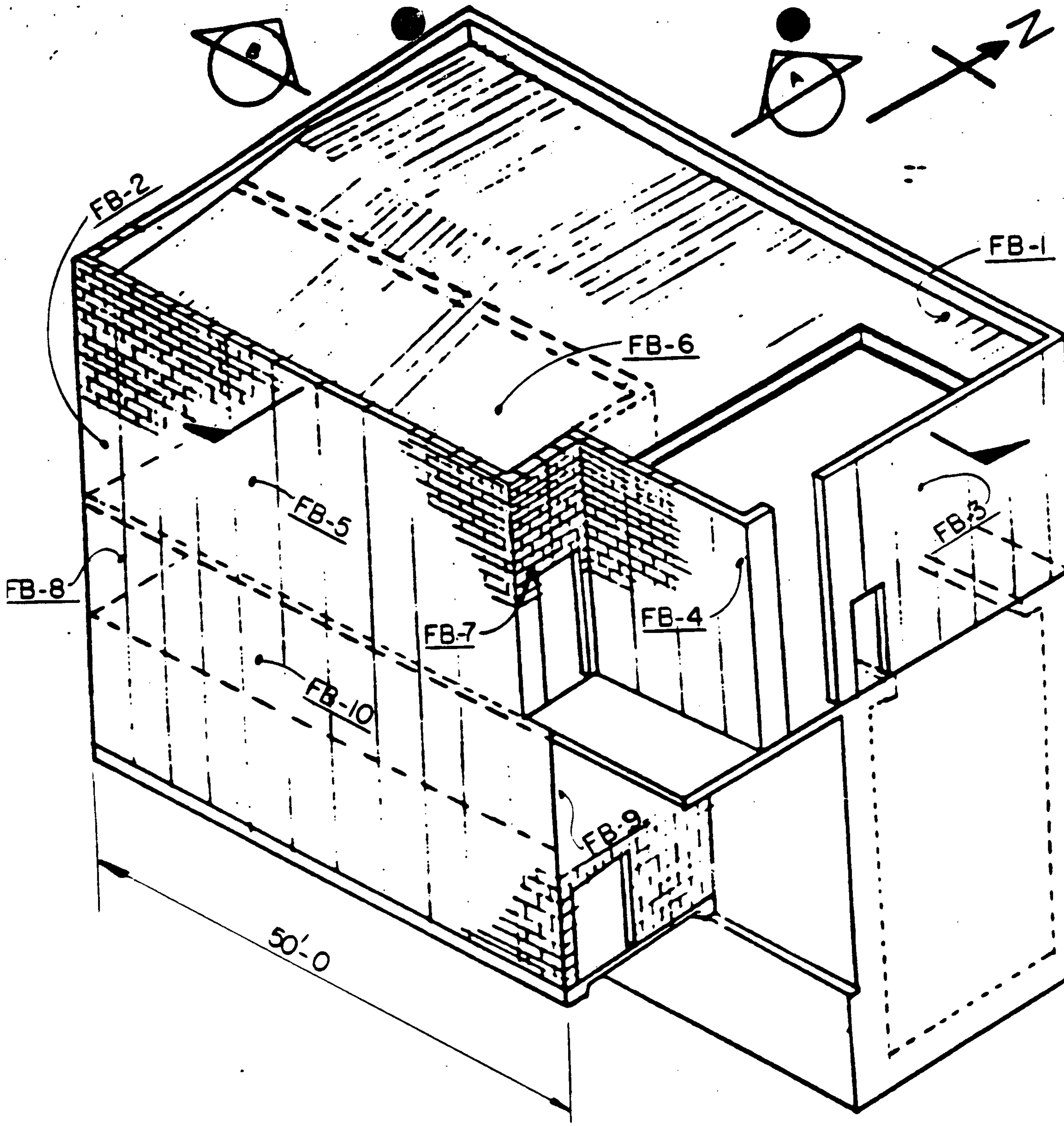

FIGURE 1.1 : GENERAL VIEW OF STRUCTURE

Question #2:

Document that the reinforcing in Section M of Drawing 568140 is equivalent to the bottom connection reinforcement used in the test program.

Response:

As was stated in our submittal of October 27, 1984, the vertical reinforcement is #7 at 32" (A_s - 1.80 sq. in. for 3 bars). The bottom connection used in the test program is 6 #5 bars (A_s - 1.86 sq. in.). This is a difference of 3%. However, walls FB-5 and FB-2 are dowelled into the slab by #5 dowels at 12" centers and on one side bear against the 9' thick slab either of which are more than sufficient to offset the minor difference in the steel areas. Therefore, the continuous walls have a better moment capacity than the test specimens.

Question #3:

For wall FB-5 verify the extent of grouting above elevation 42'.

Response:

Section M of Drawing 568140 does not explicitly describe the extent of grouted cells above elevation 42'. To verify whether the cells were grouted or not, a field investigation was made. At two locations, about 30' apart, holes were drilled into the first three cells above elevation 42'. The holes were situated about halfway between the vertical rebar. Grout was encountered in all holes. In addition, it was found that there was a continuous horizontal bar in or slightly above the third cell. This investigation indicates that there is a bond beam above elevation 42', with an "as-built" condition as shown in Figure 3.1.

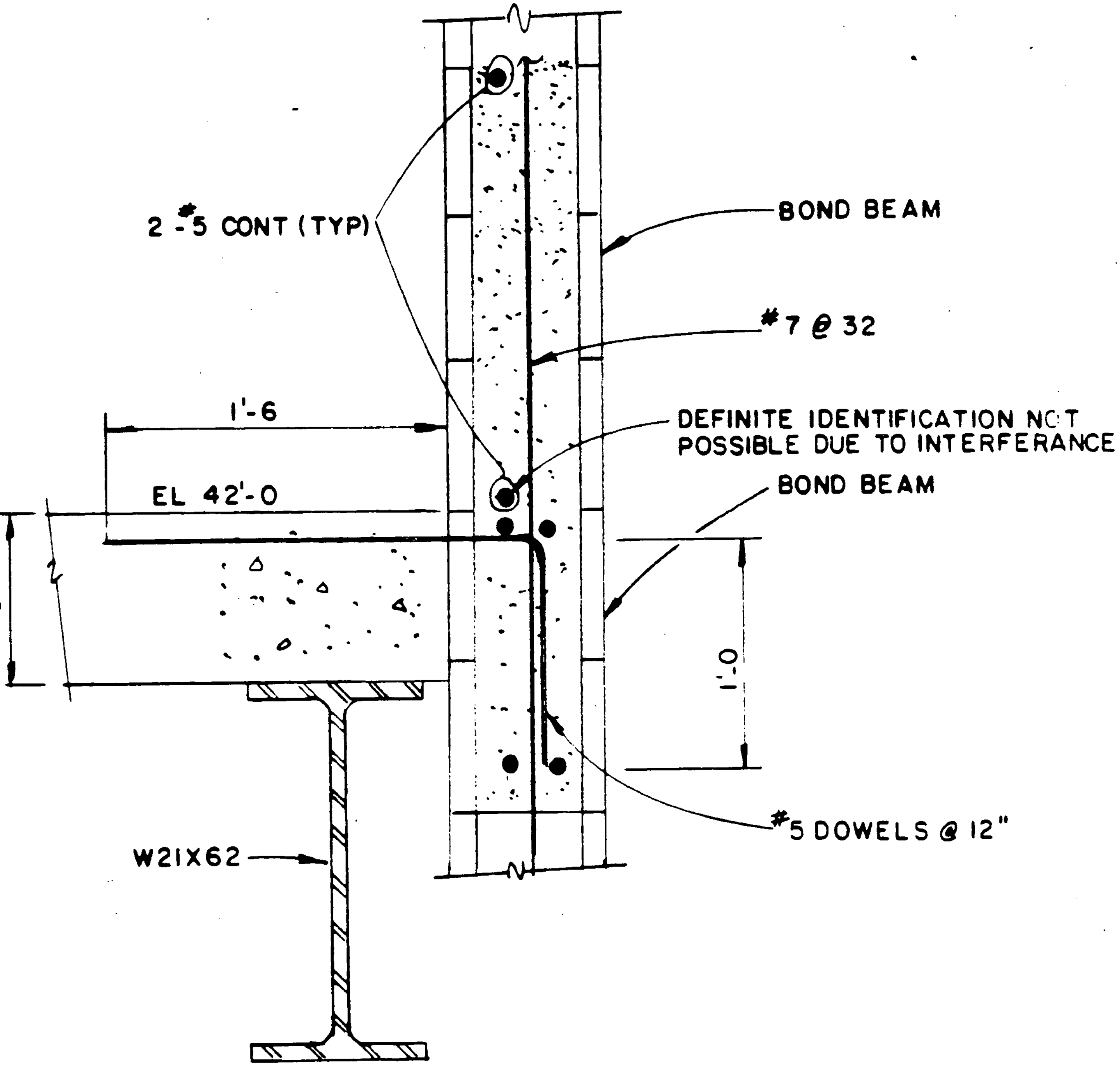

FIGURE 3.1 SONGS-1 FUEL STORAGE BLDG.
AS-BUILT DETAIL AT EL 42'-0

Question #4:

Examine the stress-strain profiles for both the test results and the analytical results to determine the position of the neutral axis.

Response:

The following sub-sections discuss the procedures used to compute the position of the neutral axis for both the analytical results and the tests. Results and conclusions from these calculations are presented.

1. Neutral Axis from Analytical Procedures

It has been explained in previous reports on the inelastic methodology that the procedures provide face shell stresses rather than strains. In an earlier response to the NRC, a method for developing stress and strain profiles was used to obtain estimates of the maximum face shell strains (see "Evaluation of Reinforced Concrete Masonry Walls, Response to NRC Review of Methodology," Appendix A, Section 3 submitted by letter dated April 30, 1982). This procedure has been used to evaluate the compression stresses in Wall Type 1.

1.1 Computation of Stresses

The earlier response was prepared at a time when the Fuel Storage Building walls were not included in the evaluation and so the strains for walls similar to Test Type 1 were not evaluated. However, the procedures developed then have now been applied to the analytical results of the Fuel Storage Building walls.

The procedure is based on the assumption that the wall deforms as two rigid blocks with a uniform curvature over the plastic hinge regions. The curvature is computed from the wall geometry, maximum deflection and assumed plastic hinge length. An assumed bi-linear masonry stress-strain curve is then used to compute the stress distribution such that the total compressive force equals the force in the yielding rebar.

For test wall Type 1 the geometry, maximum deflections and strengths of the steel and masonry are known from the test results. The stress-strain curve assumed in the previous response was used, with a linear slope of 500f'm up to strains of 0.002 and a falling branch of -83.3f'm beyond this level. The average deflection from the three tests on wall Type 1, 11.20", was used. The plastic hinge length at the base and the mid-height is different and thus this parameter was varied in the calculations, from 18" to 72".

1.2 Results of Calculations

The results of the computations are summarized in Table 4.1 and Figure 4.1. Table 4.1 lists the maximum strains and the distance from the extreme fiber to the neutral axis for various values of plastic hinge length. In Figure 4.1 the strains are plotted below the horizontal line representing the face shell and the stress distribution corresponding to the strains are plotted above the line. For the plastic hinge lengths used, the lower value (18") would correspond to the base hinge and the larger values (42" to 72") would be appropriate for the mid-height hinge. Therefore, maximum strains at the base hinge would be of the order of 0.0067 with a neutral axis 0.78" into the face shell. For the upper hinge the strains would be 0.0030 with depths to the neutral axis of about 0.8" to 1.0". Note that at the base, even though strains are higher, the neutral axis depth is less because of the higher curvature associated with the lower plastic hinge length.

TABLE 4.1: COMPUTED STRAINS AND NEUTRAL AXIS DEPTHS

Plastic Hinge Length	Maximum Compressive Strain	Depth from Extreme Fiber to Neutral Axis
18.0"	0.0067	0.78"
30.0"	0.0040	0.78"
42.0"	0.0031	0.84"
56.0"	0.0026	0.92"
72.0"	0.0022	1.02"

At the time the April 30, 1982 response was prepared, a limit of 0.004 was suggested for the extreme fibre strain. Beyond this strain the potential for face shell spalling would exist. In fact, the indicated values of strain in Figure 4.1 and Table 4.1 show that spalling would not occur at the mid-height hinge but would be a possibility at the base. In the test, no spalling occurred at mid-height and only minor spalling at the base occurred, i.e., approximately 1/4" to 1/2" into the block.

The maximum depth to the neutral axis at the wall base has been computed to be approximately 0.7 inch, or less than one-half of the actual face shell thickness. On this basis even with spalling up to 3/4 inch, the neutral axis would remain in the face shell. The tested walls exhibited spalling about one half this value.

2. Neutral Axis from Test Results

The position of the neutral axis was not part of the data reduced from the original test results. In an attempt to obtain meaningful values, the test results have been reinterpreted to compute positions of the neutral axis at each time step at which data was recorded.

2.1 Method of Computing Neutral Axis Position

Computation of the neutral axis position has been performed by using the simultaneous compression strain and gap readings on opposite sides of the wall to compute the strain profile and therefore position of the neutral axis. This has been done at three vertical locations for each of the three specimens of wall Type 1; two at approximately mid-height (one at the position of maximum strain and one at the position of maximum deflection) and the third at the base of the wall.

2.2 Factors Effecting Test Results

The method used to compute the neutral axis position is conceptually simple but there are a number of factors which must be taken into account in interpreting the results:

1. Where strains are very small (total movement over the gage length of less than 0.0005) the accuracy of the recording instruments is insufficient to obtain accurate values. This generally applies to the first 4 to 6 seconds of each record where the motion was low and the wall uncracked.

2. Initial cracking generally occurred on only one side of the joint rather than through the entire block width. In this case the neutral axis varies between the center of the block (0.0" on the plots) to the face of the block, depending on the direction of loading. This situation generally applied from about 4 to 8 seconds of the record.

3. Strain gage malfunctioning or out-of-range movements in some cases invalidated the data, as noted in the test report.

4. At the base of each wall specimen,minor mortar spalling occurred, up to about 1/2" into the block. Because of this the recorded DCDT values and subsequent conversion into face shell strains and neutral axis positions were invalidated.

As a consequence of these factors, some judgement is required to be exercised in the interpretation of the results.

2.3 Results from Test Data

Time histories which were not impacted by Items 3 and 4 of the previous section are presented in Figures 4.2 to 4.7. Time histories which were impacted by either spalling or malfunctioning instruments are presented for completeness in Figures 4.8 to 4.10. Valid test data was obtained at the two mid-height locations but not at the base on wall 1A; for wall 1B valid data was obtained at the base and both mid-height locations and for wall 1C valid data was obtained only at one mid-height location.

A. Wall Test 1A. Figures 4.2 and 4.3 present the valid results from wall Type 1. These are both mid-height locations and appear to give valid results except for a few high frequency "spikes" in Figure 4.3. These spikes result from noise in the recording instruments because they are of much higher frequency than the wall response. Figure 4.8, at the base of wall 1A, does not provide any valid data because the DCDT became loose and went out of range.

At the mid-height locations, the depth to the neutral axis at DCDT05 was a maximum of approximately 1.0" after cracking had occurred on both sides (after 9 seconds in Figure 4.2) and a maximum of approximately 1.4" at DCDT09 (after 11 seconds in Figure 4.3). This latter value seems to be influenced by some high frequency spikes which may be spurious.

B. Wall Test 1B. Figures 4.4 to 4.6 present the neutral axis positions for wall Type 1B at all three locations. Figures 4.4 and 4.6 apparently give valid data after cracking has occurred (approximately 6 seconds). Figure 4.5 has a number of pulses on the frame side which appear anomalous and less credibility has been given to this result.

For wall Type 1B the depth to the neutral axis is approximately 1.2" at mid-height and 0.8" at the base hinge.

C. Wall Test 1C: Of the three positions evaluated for wall Type 1C, only one location at mid-height provided valid data (Figure 4.7). The other two sets of results are given in Figures 4.9 and 4.10. At the mid-height location, the depth to the neutral axis reached a maximum value of 1.0".

For wall Type 1C, the maximum recorded readings of gap and strain at the base occurred simultaneously and so a neutral axis position could be computed at this time instant, even though the plot in Figure 4.10 provides no valid data. This value was 0.64".

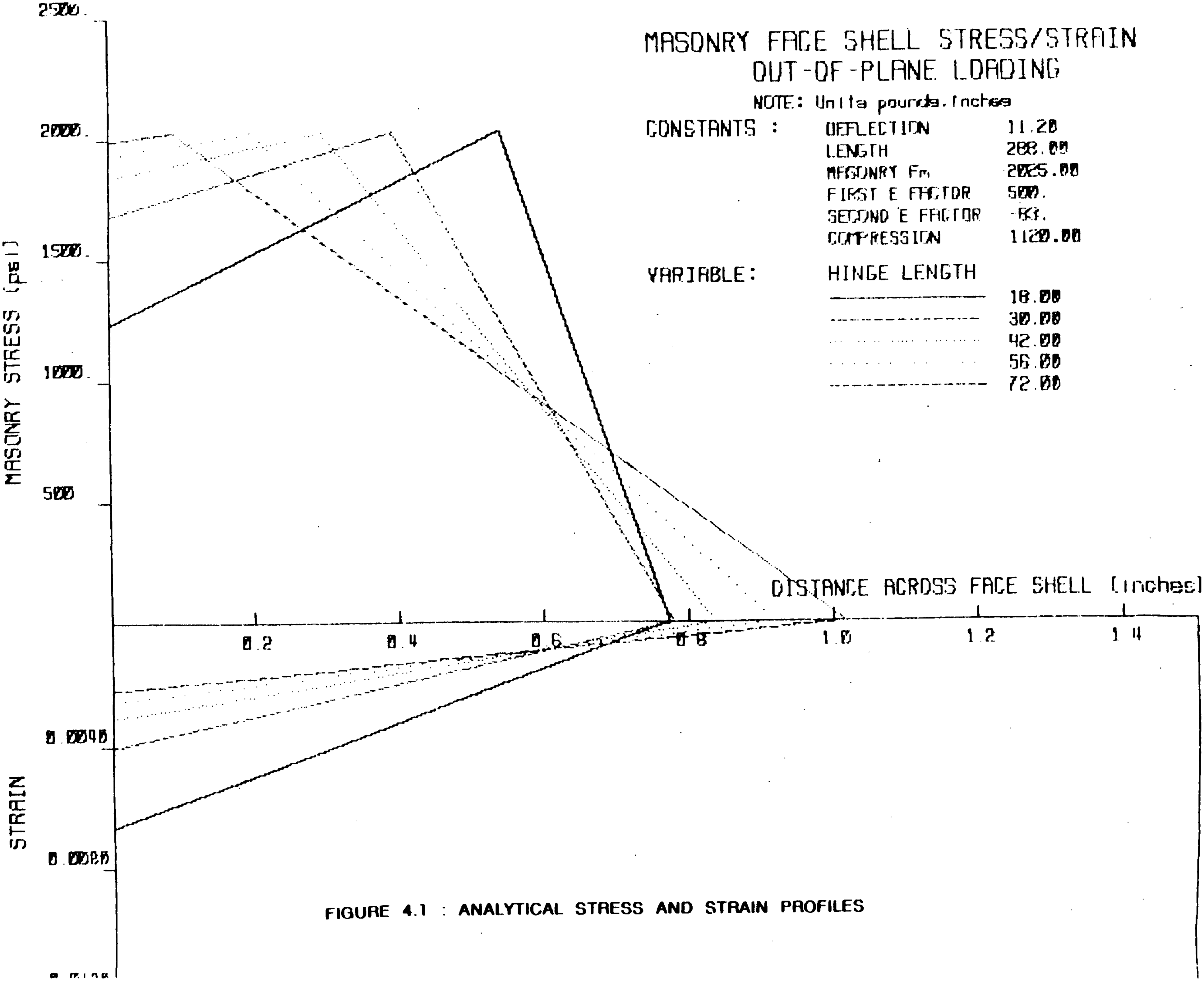

FIGURE 4.1 : ANALYTICAL STRESS AND STRAIN PROFILES

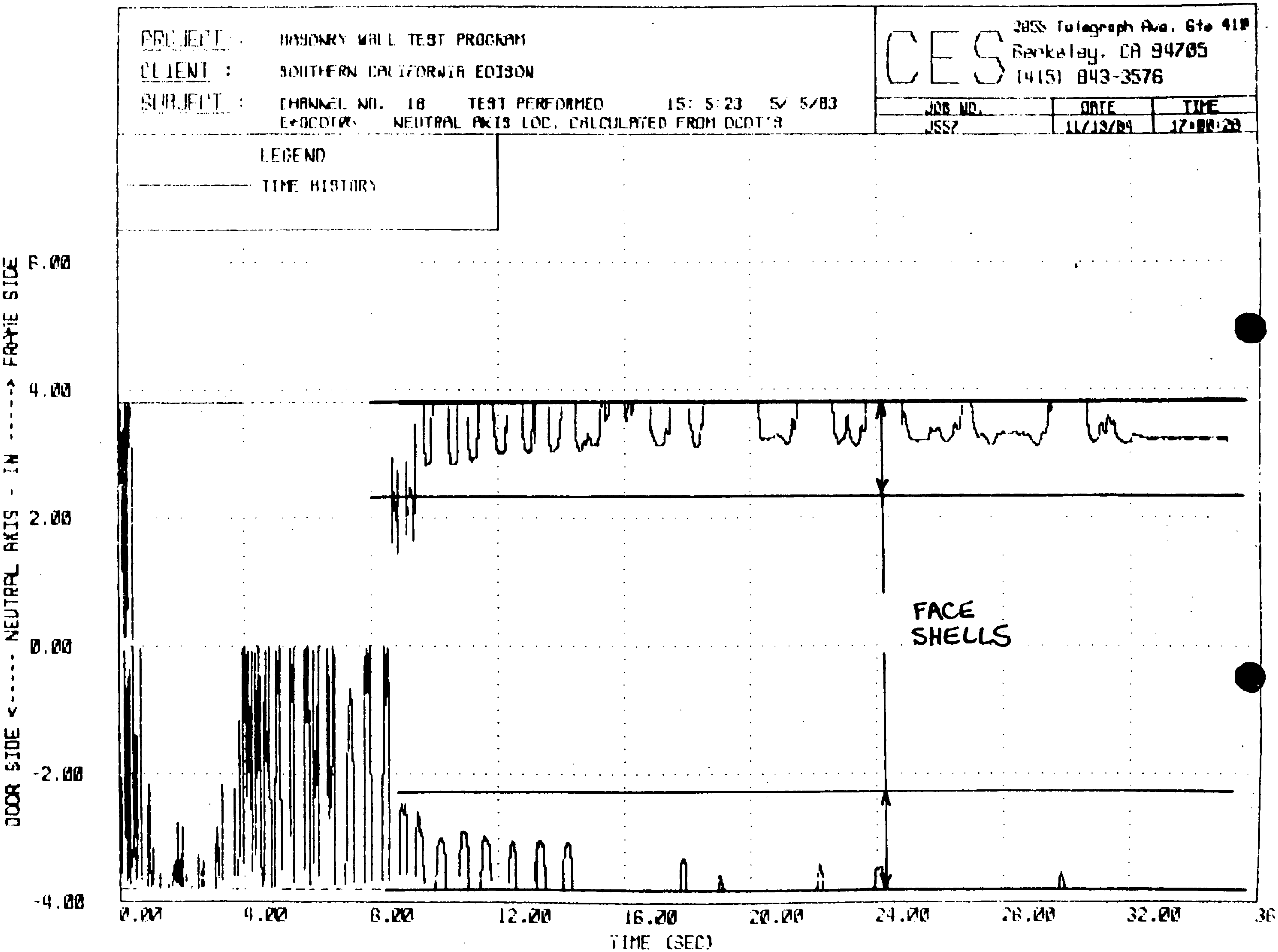

FIGURE 4.2 : NEUTRAL AXIS POSITION FROM TEST : WALL 1A MID-HEIGHT

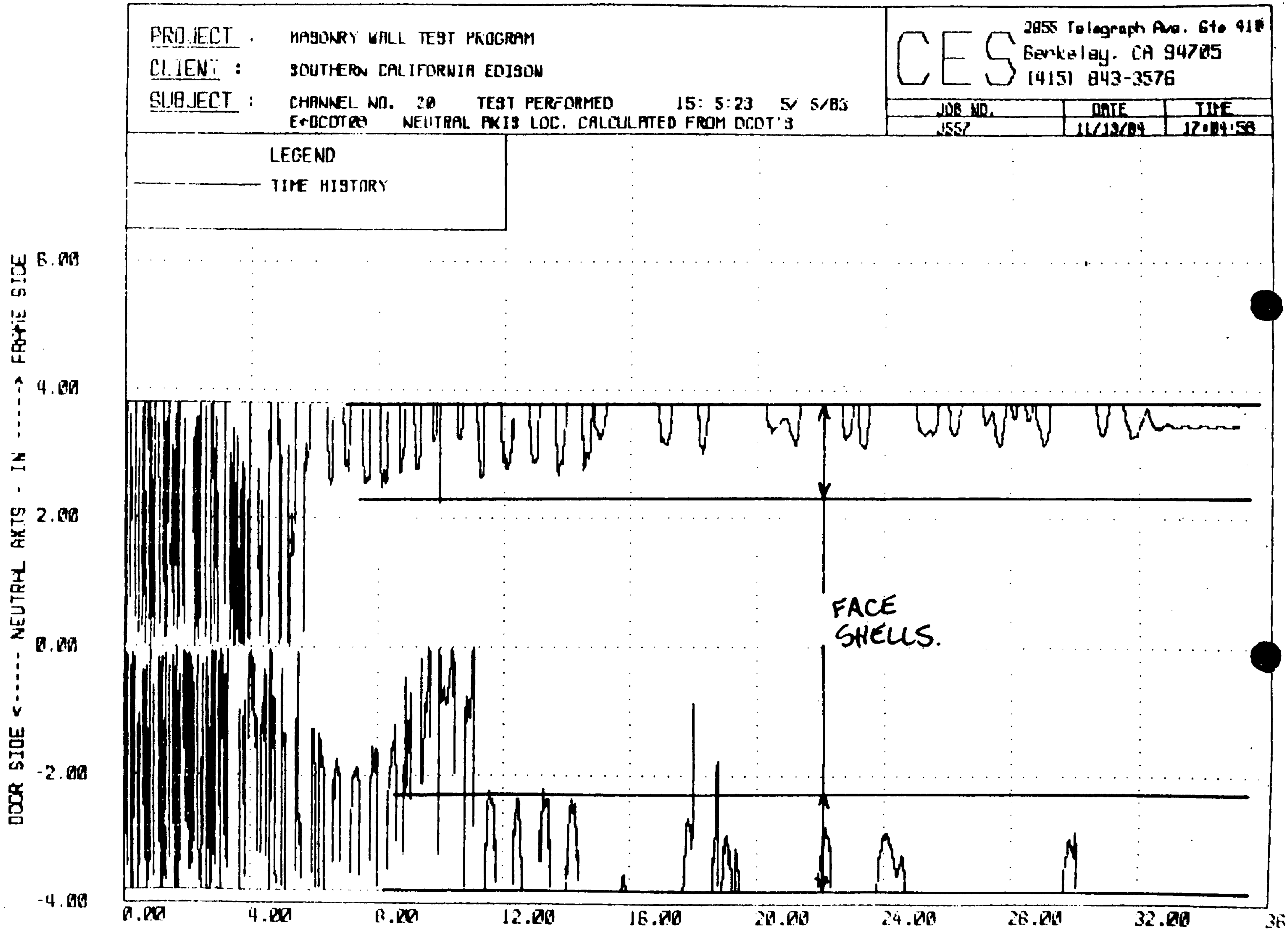

FIGURE 4.3 : NEUTRAL AXIS POSITION FROM TEST : WALL 1A MID-HEIGHT

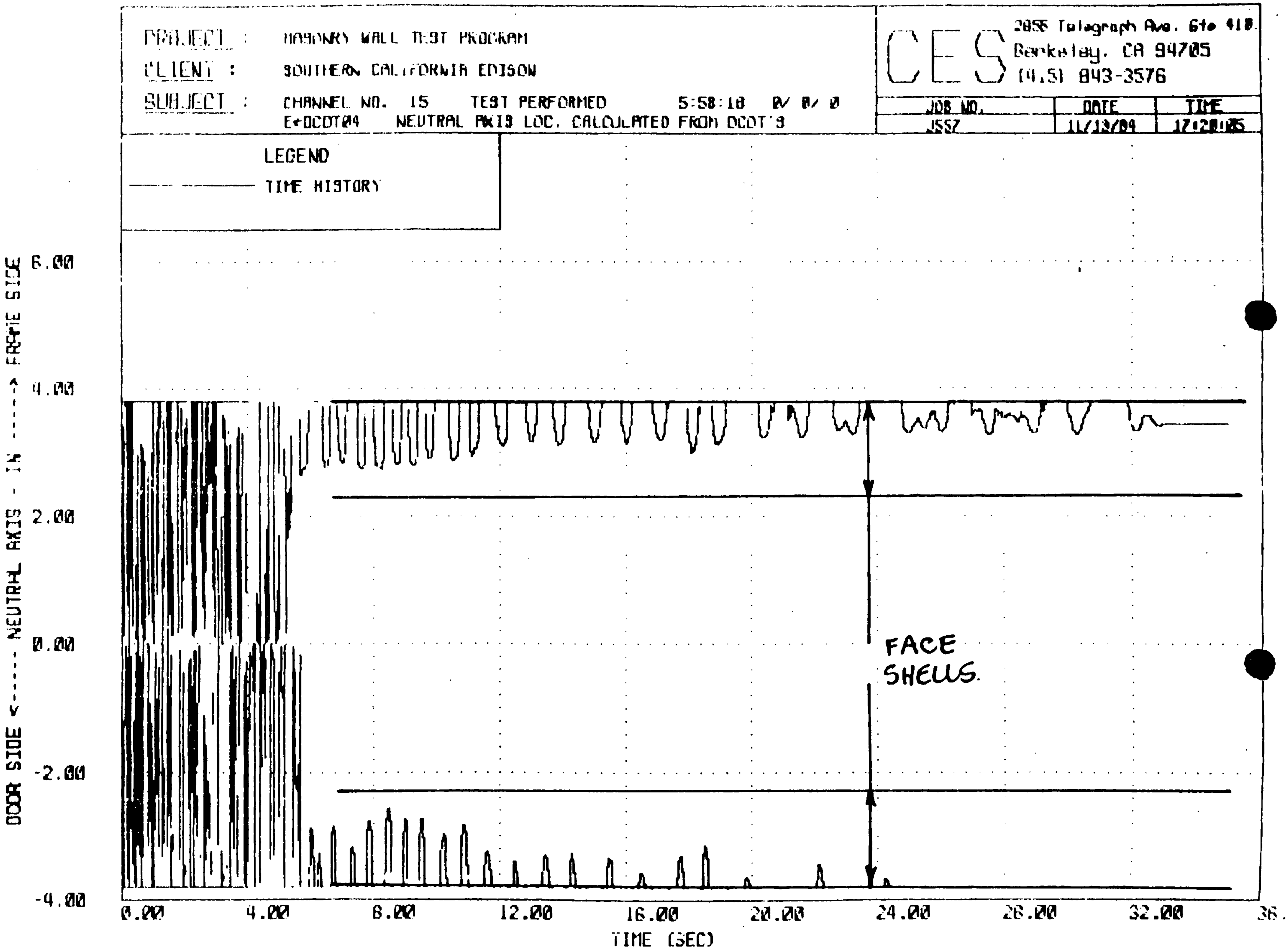

FIGURE 4.4 : NEUTRAL AXIS POSITION FROM TEST : WALL 1B MID-HEIGHT

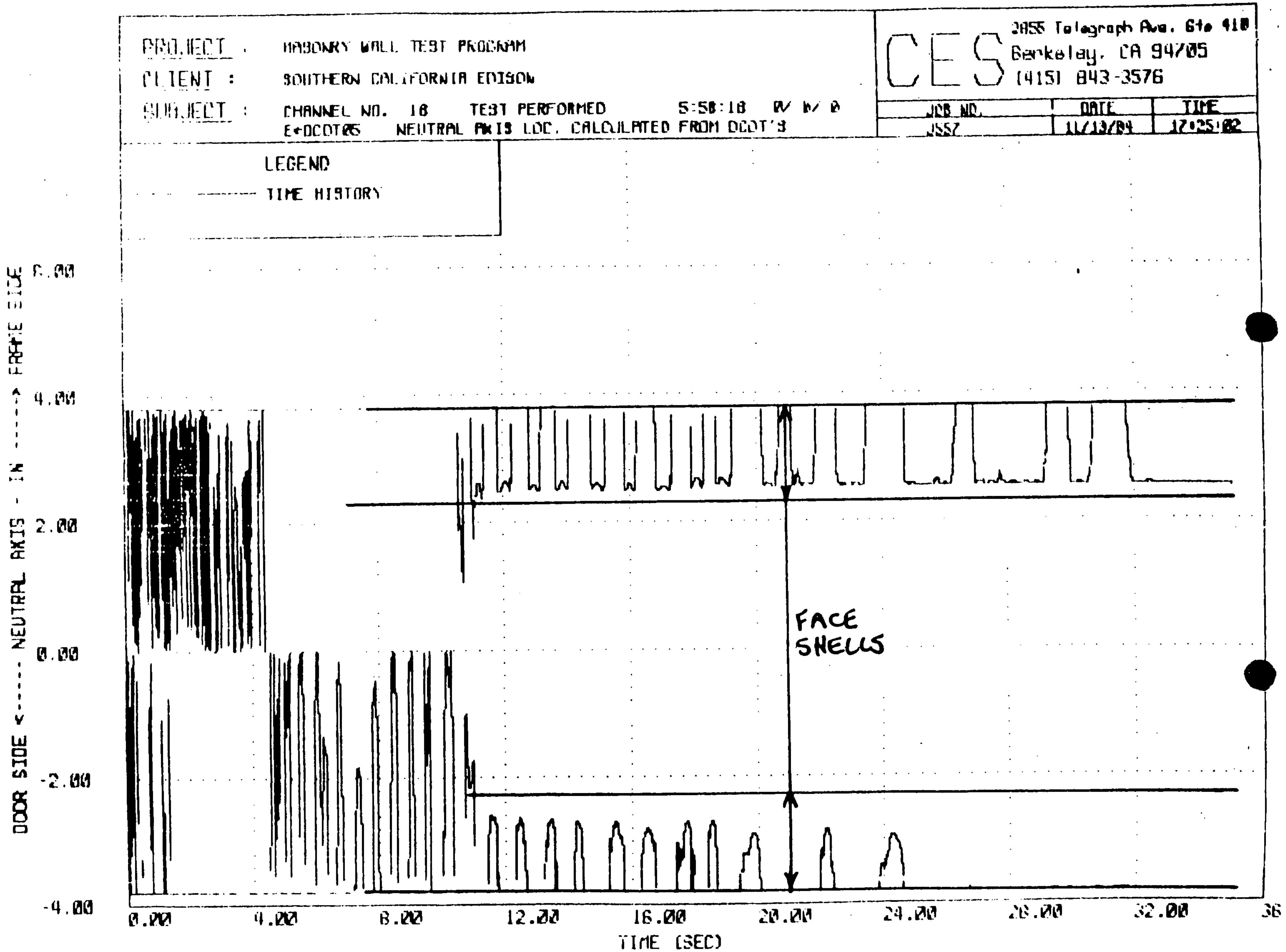

FIGURE 4.5 : NEUTRAL AXIS POSITION FROM TEST : WALL 1B MID-HEIGHT

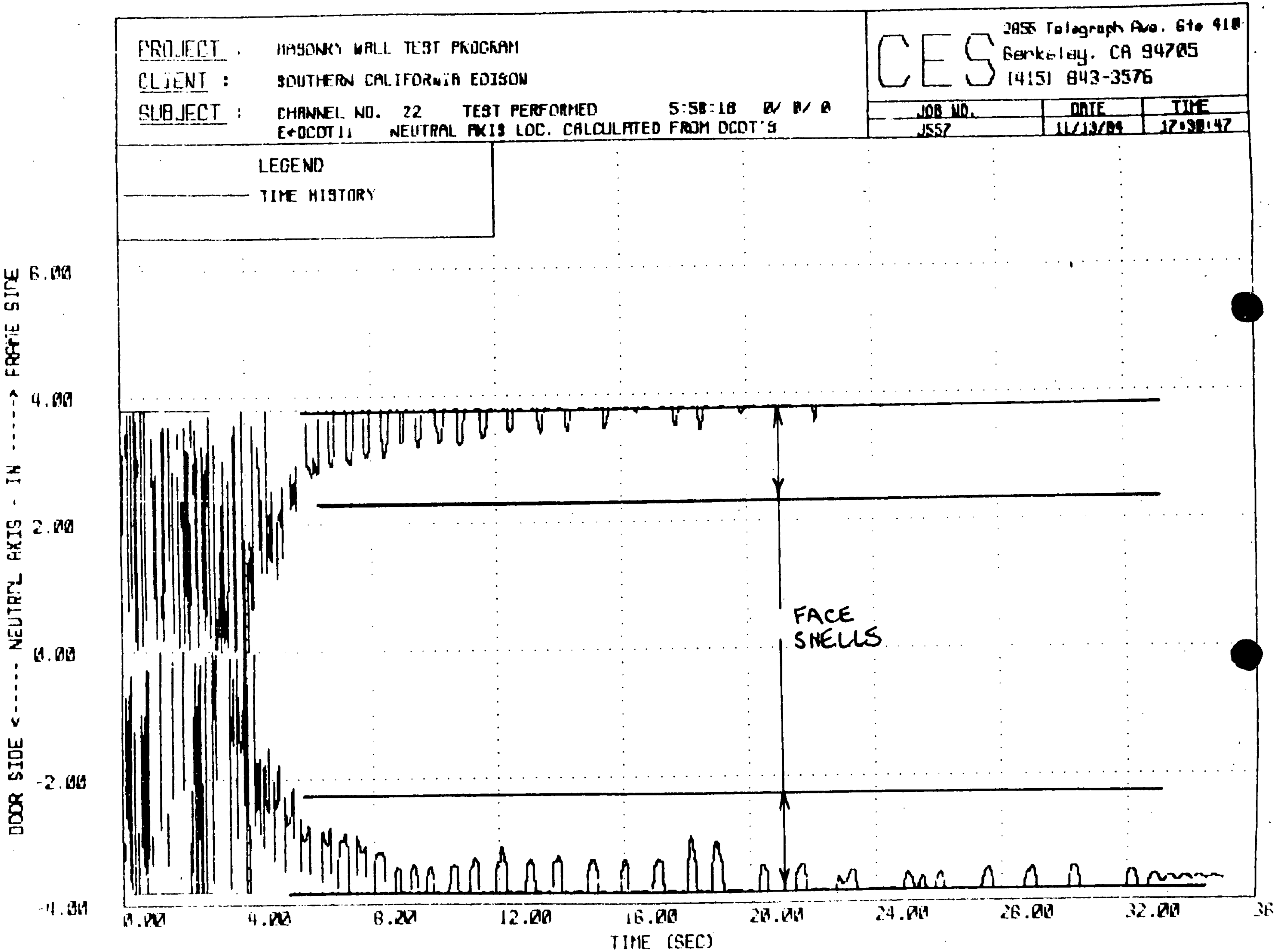

FIGURE 4.6 : NEUTRAL AXIS POSITION FROM TEST : WALL 1B BASE

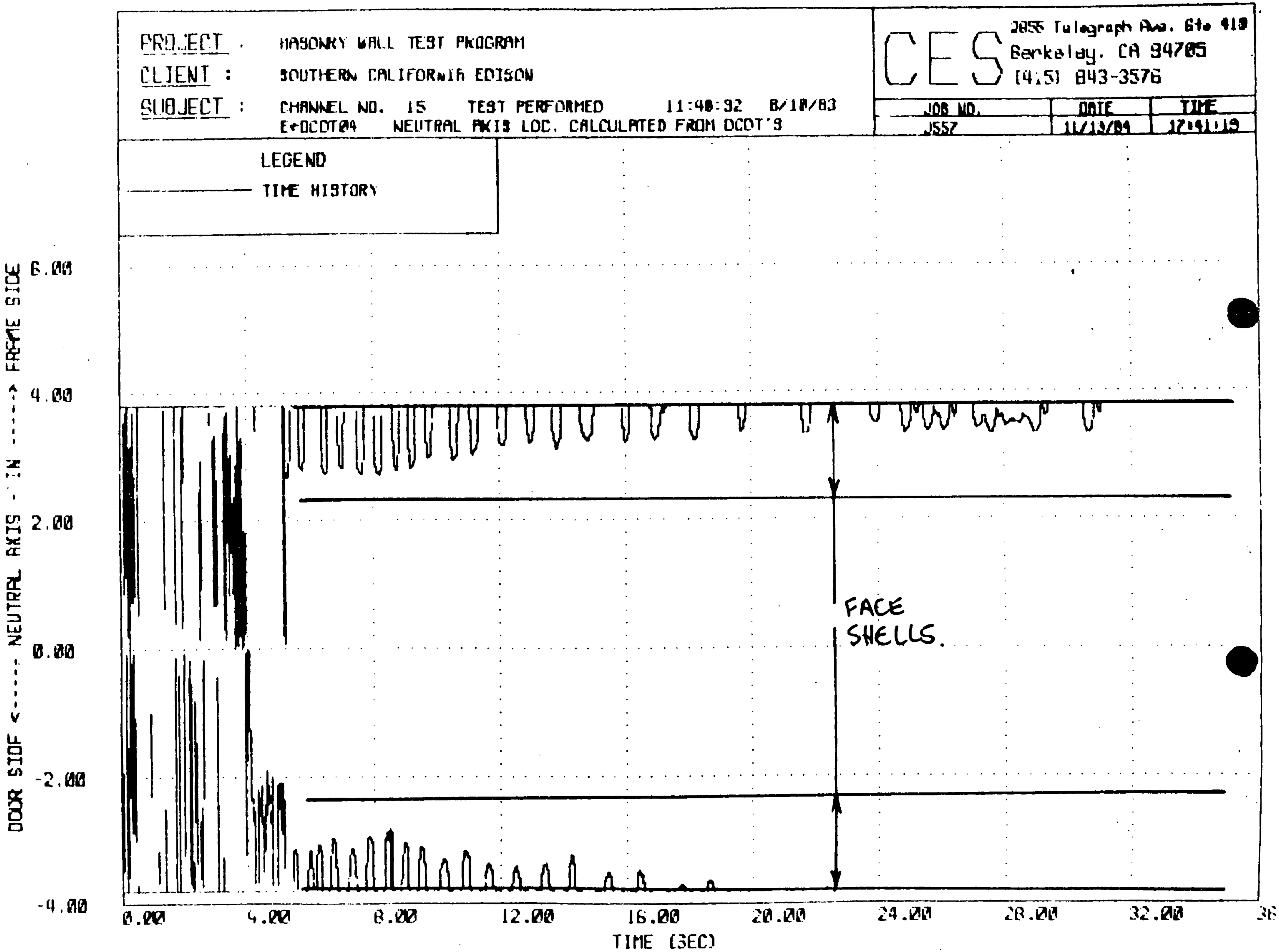

FIGURE 4.7 : NEUTRAL AXIS POSITION FROM TEST : WALL 1C MID-HEIGHT

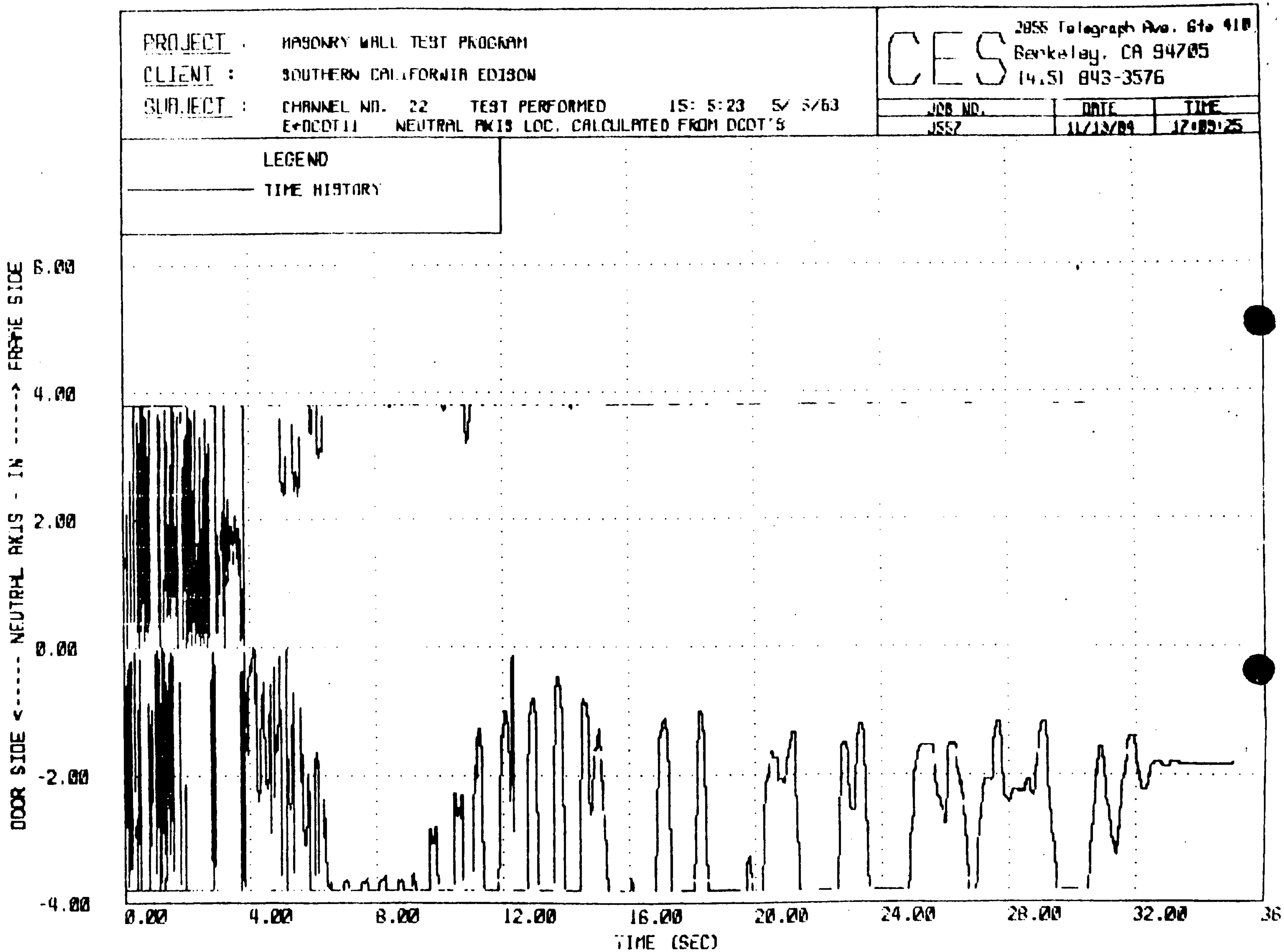

FIGURE 4.8 : NEUTRAL AXIS POSITION FROM TEST : WALL 1A BASE

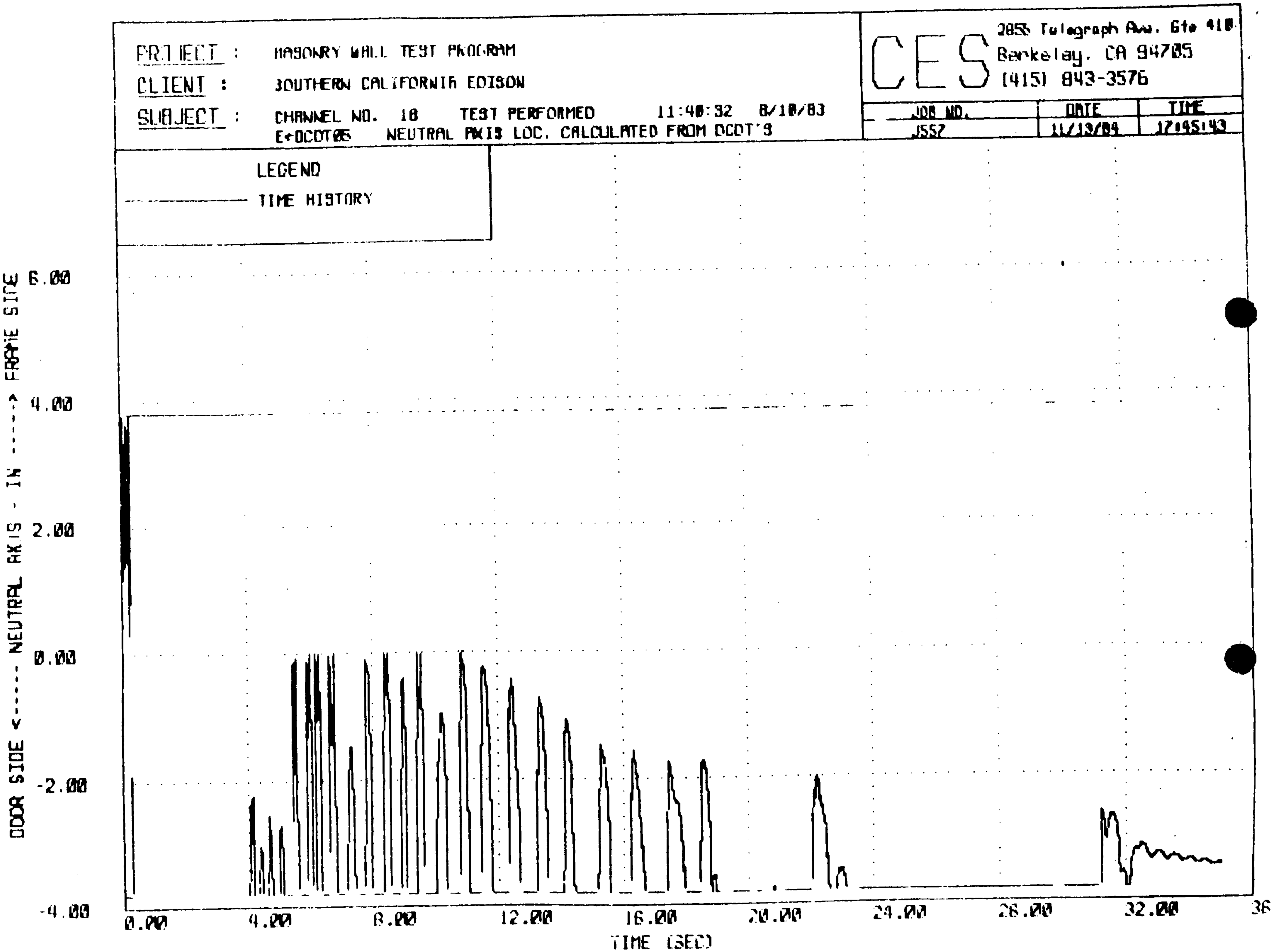

FIGURE 4.9 : NEUTRAL AXIS POSITION FROM TEST : WALL 1C MID-HEIGHT

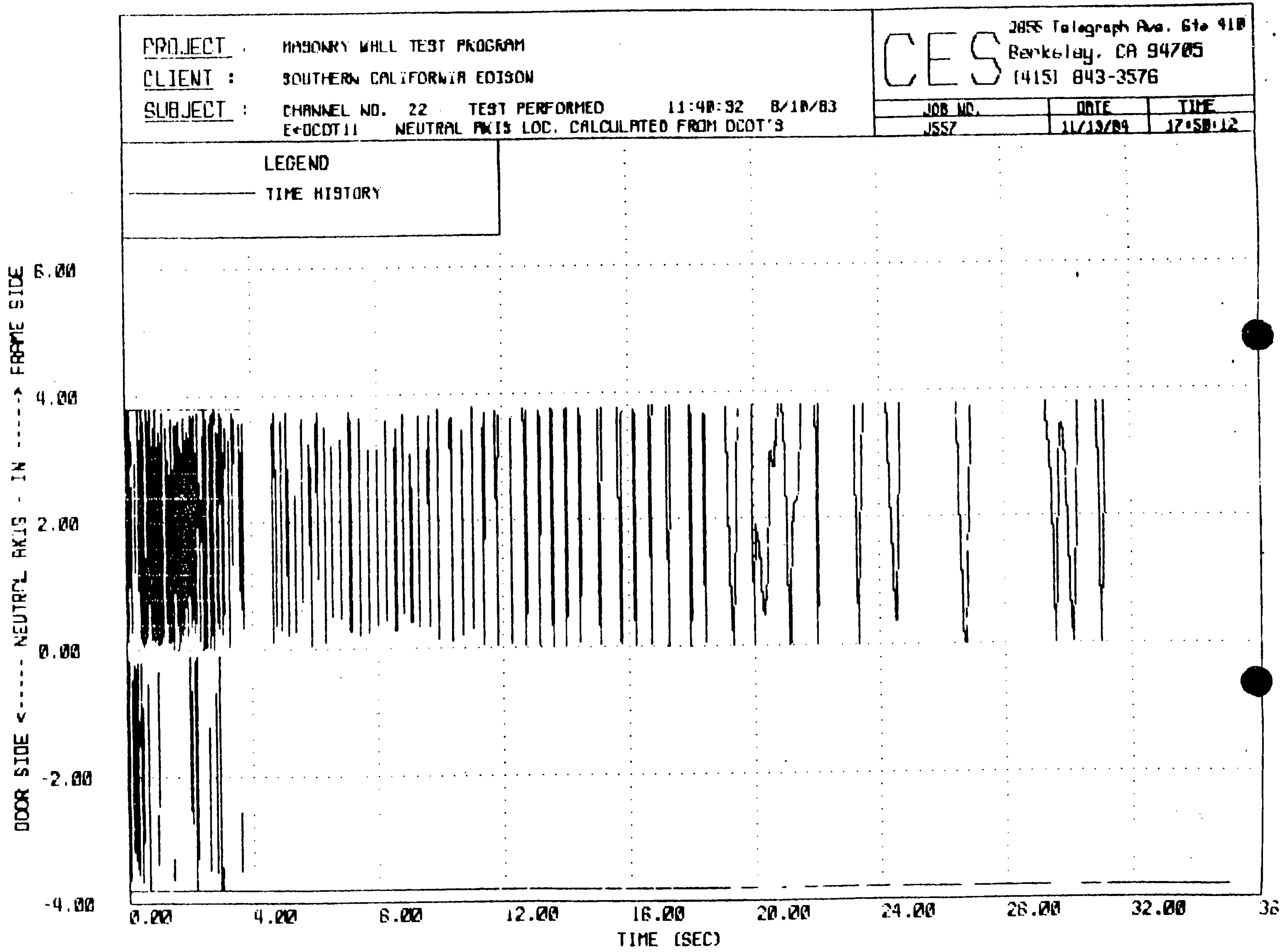

FIGURE 4.10 : NEUTRAL AXIS POSITION FROM TEST : WALL 1C BASE

3. Summary of Neutral Axis Positions

The analytical predictions for values of the neutral axis position were 0.8 inches and 1.0 inches for the base and mid-height hinges, respectively. These values are measured from the extreme compression fiber and are well within the face shell thickness of 1.5".

From the test data it was difficult to obtain a definitive value of neutral axis positions due to the need to have accurate simultaneous data on each side of the joint at each time step. From the evaluation performed, depths to the neutral axis appear to be from 1.0 to 1.4 inches at the mid-height hinge and 0.6 to 0.8 inches at the base hinge. These values correlate reasonably well with the analytical results and again are within the thickness of the face shell.

Question #5:

Determine the location of the positions at which the maximum stresses and strains occurred for wall FB-5.

Response:

Maximum Stresses in Analysis

The maximum stresses in the analytical results reported were at the base of the wall where the higher steel ductility values occurred (20.7 compared with 18.7 at the mid-height hinge). This difference is more marked in the stress-strain curves plotted in Figure 4.1 where the shorter plastic hinge lengths at the base cause strains about twice as high. However, because the curvature is higher for the shorter plastic hinge lengths for a given plastic rotation, the neutral axis at the base of the wall was closer to the outer fiber than it was at mid-height.

Maximum Stresses from Tests

The test results were similar to those of the analysis in that maximum strains at the base were considerably higher than at mid-height. However also as for the analytical results, computed depths to the neutral axis were lower at the base because of the higher curvature.

Question #6:

Verify that the results from the test program are applicable to wall FB-5.

Response:

The applicability of the test program to wall FB-5 has been assessed in terms of what are considered to be the pertinent features of wall response, as follows:

1. The reinforcing area is the same in the tested walls and in wall FB-5, i.e., #7 at 32" o.c. The tested walls had #5 dowels at 16" immediately above the base, providing the same total area of steel.

2. The test walls had rebar splices at the region of the base hinges whereas wall FB-5 has continuous rebars. This detail for FB-5 is superior to that of the tested wall for the development of a plastic hinge. If any problems were to occur with bond, they would be apparent in the test specimens. This did not occur and thus FB-5 will be capable of developing a plastic hinge.

3. Wall FB-5 is grouted (as noted in the response to Question 3) for three courses above Elevation 42'-0", as were the test specimens. In addition, analytical results and test data confirm that the neutral axis at the base and the wall mid-height hinge regions is always within the face shell. Therefore, even if the grout were absent in the central core, the compression capacity of the wall would not be affected.

For these reasons, it is considered that the wall configuration selected for wall Type 1 represented the "worst case" of the 24 feet high walls at SONGS 1 and the test results are applicable to wall FB-5.

DA:3091F