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July 25, 1983

Dr. P.T. Kuo
Structural Engineering Branch
Room No. 550
Phillips Bldg.
7920 Norfolk Avenue
U.S. Nuclear Regulatory Commission
Bethesda, MD 20814

Dear Dr. Kuo:

This letter report describes the work performed by BNL on the review and evaluation of the buried fuel tanks utilization the Diablo Canyon Plant. The work was completed in May of 1983 and the results were presented in a public meeting held in Bethesda, MD on June 17, 1983.

As a consequence of this meeting some additional investigations using refined models were performed. Results of the latter studies were presented in a "follow-up" meeting held in Bethesda, MD on July 6, 1983. This letter report summarizes the BNL efforts for this particular task which is now considered as complete.

Essentially, the work carried out under this task, can be subdivided into the following three categories.

1. Review of soil structure interaction (SSI) models used by Harding and Lawson Associates for the 1978 and 1982 seismic evaluations.

2. Develop SSI computer models and calculate stresses and safety factors.

3. Construct refined models and perform SSI seismic evaluations.

A more detailed description of each of the above items is given below:

1. The work carried out by Harding and Lawson on the seismic evaluation of the buried tanks was reviewed. Specifically this review included:

a) The Harding and Lawson results reported in the seismic part of the 1978 report (see Ref. 1).

b) The Harding and Lawson 1982 re-analysis described in the letter report (see Ref. 2).

The objective for reviewing the 1978 work was to identify a variety of data, i.e., soil properties, damping values, etc., needed for the subsequent BNL evaluations. The dynamic response of the tanks due to the Newmark-Hosgri event was reviewed on the basis of the 1982 re-analysis results. The FLUSH model of the soil-tank system used by Harding and Lawson in the 1982 re-analysis is shown in Fig. 1a. A lumped mass model was constructed (see Fig. 1b) with the fluid modeled as lumped masses rather than finite elements. The objective for developing this model was to obtain a quantitative appreciation of the effect of the fluid on the seismic response of the tank. Seismic responses due to the Newmark-Hosgri earthquake applied in the horizontal direction using the lumped mass model were obtained with the FLUSH computer program. The results of this analysis are shown in Table 1 together with the corresponding results from the Harding and Lawson 1982 re-analysis. By inspection of the results shown in Table 1, it can be concluded that the results obtained by Harding and Lawson differ significantly from the corresponding results obtained by BNL via the lumped mass model. It was felt that this difference cannot be justified on the basis of the sloshing effect alone which is not included in the lumped model. The sloshing effect would usually be expected to alter the response by 10 to 20%. Sloshing frequencies were calculated and found to be very low, i.e., 0.1 Hz. As such, they should not have important effects on the response of the tank. In view of this, BNL concluded that the significant differences between the Harding and Lawson model and the lumped model constructed by BNL were due to the fluid elements used in the Harding and Lawson model.

In reviewing the computer printout from the FLUSH code, it was observed that the Poisson's ratio value used for the fluid elements was equal to 0.4999, whereas, the instructions in the FLUSH manual clearly state that this value must be below 0.49. Thus, initially it was suspected that this was the problem. In reflecting upon this problem and the flexural ring modes that occur in such a structure, BNL came to the conclusion that such modes could not exist in the Harding and Lawson model because of the inappropriate fluid modeling. Specifically, as a result of the finite element descretization used by Harding and Lawson, the fluid is not allowed to perform its natural motion. Results from a finer grid indeed, proved this BNL position.

2. The subtasks completed under the second work category are:

    a) BNL FLUSH model development.

    b) Deconvolution studies.

    c) Soil-structure interaction response evaluations.

    d) Evaluation of stresses and safety factors.

The FLUSH model, shown in Fig. 2, was used for the response evaluation of the soil-tank system normal to the tank axis (transverse response). Inside the trench, it was decided to construct the model in a similar fashion to the one used by Harding and Lawson (Z-Z section) for the 1982 re-analysis. The major difference, however, was that the mass of the oil was lumped at the walls of the tank. This approach although, somewhat conservative, was found to be more appropriate than that of the fluid element idealization employed in the 1982 re-analysis model by Harding and Lawson. Furthermore, in the BNL model, the transmitting boundaries were moved further away from the tank walls. This was done to avoid possible reflections at the boundaries.

Before performing any response evaluations with this model, deconvolution studies were undertaken. The Newmark-Hosgri acceleration pulse was used at the surface and by deconvolution the input at the base of the soil-tank system was obtained. For the deconvolution studies the SLAVE code was employed. Results from the SLAVE code were compared with those obtained from the FLUSH code. The two results matched quite well.

Using the FLUSH model and the deconvolution results described above, the response of the tank was evaluated via soil-structure interaction analysis. Frequencies up to 30 Hz were included. Horizontal and vertical evaluations were carried out. In these evaluations, the Newmark-Hosgri acceleration time history was applied directly at the base of the soil-tank system. In addition to these evaluations, analysis were made with the acceleration time history obtained from the deconvolution.

Due to the nonlinearity of the problem, five iterations were performed in all evaluations, i.e., horizontal - vertical and with - without deconvolution.

The results of the soil-structure interaction evaluations were moments, axial and shear forces associated with the beam elements representing the tank walls. Based on these results, a stress evaluation was carried out. The

seismic stresses obtained by BNL were then combined with the static stresses given by Harding and Lawson in their 1982 static re-analysis. Based on the total stresses (i.e., static dynamic) safety factors were computed. In evaluating the safety factors the same approach as that used in the 1982 re-analysis was employed. These safety factors are depicted in Fig. 3.

3. At the first meeting with the project staff held on June 17, 1983, BNL's position was that the fluid modeling used by Harding and Lawson was crude. It was felt that because of this, the response evaluation of the tank performed by Harding and Lawson could be inappropriate. To prove this position, BNL carried out some further investigation which included the following subtasks:

a) Development of a BNL refined FLUSH model.

b) Code modification to include fluid elements.

c) Soil-structure interaction evaluations using the BNL refined model.

d) Evaluation of a partially filled case.

The BNL refined FLUSH model is shown in Fig. 4. This model was essentially constructed from the Harding and Lawson 1982 re-analysis model. The finite element grid of the fluid, however, was as can be seen substantially, refined. Two types of soil properties were assigned to the model. These are the ZZ and YY section properties.

As mentioned, the FLUSH code was modified to include a fluid element. Other modifications were also made to obtain stress response waveforms for the fluid element. This permitted the evaluation of the so called "tensile stresses" in the fluid elements. Computer runs were made with values of 0.4999 as well as with fluid elements.

Soil structure interaction evaluations were performed in the horizontal direction only. These were felt to be sufficient to prove the BNL contention regarding the modeling problem associated with the Harding and Lawson 1982 analysis model. Two sets of runs were made using the ZZ and YY section soil properties. Results are summarized in Tables 2, 3 and 4. From these it is clear that the refined model results are closer to the corresponding lumped model results. It is also fairly clear that the Harding and Lawson 1982 model differs significantly from both the refined and the lumped model. Furthermore, the responses from the YY model indicated that this model is more criti-

ical than the ZZ model. From very limited investigation, it also seems that even higher response would result if YY section properties were to be used together with deconvolution. Finally, initial computer runs made with partially filled tanks also resulted in higher response values. In these initial studies, the partially filled tank was simulated by using the model described in Fig. 4 and by assigning very low stiffness values to the top fluid layer so that it approximated a 90% filled case. For such a case, the bending, particularily, at the top portion of the tank increases. The reason for this is that due to the upward motion of the fluid inside the tank there is less fluid resistance to the tank deformations.

Sincerely yours,

Morris Reich

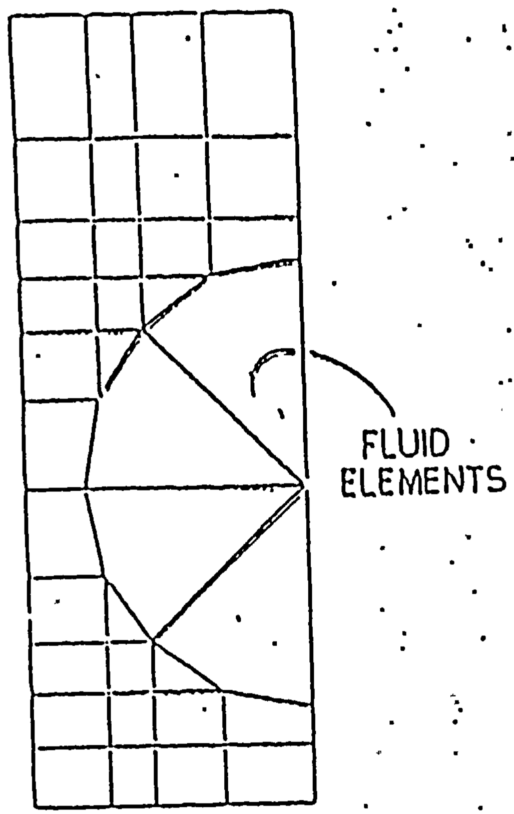
Morris Reich, Head
Structural Analysis Division

jm
Enclosures

REFERENCES

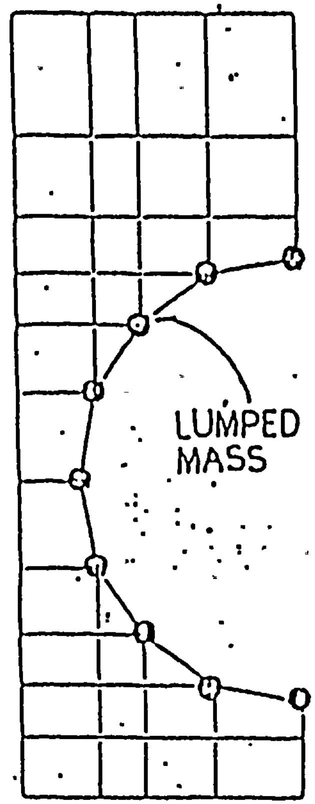
1. "Geotechnical Studies, Intake Structure, Water Storage Tanks, Diesel Fuel Oil Storage Tanks, Diablo Canyon Nuclear Power Plant, San Luis Obispo County, CA, HLA Job No. 569,031.04," Harding and Lawson Associates, San Francisco, CA, April 12, 1978.

2. Letter-Report from Harding and Lawson Associates to Pacific Gas and Electric Company, (569,049.04), October 11, 1982.



HLA MODEL

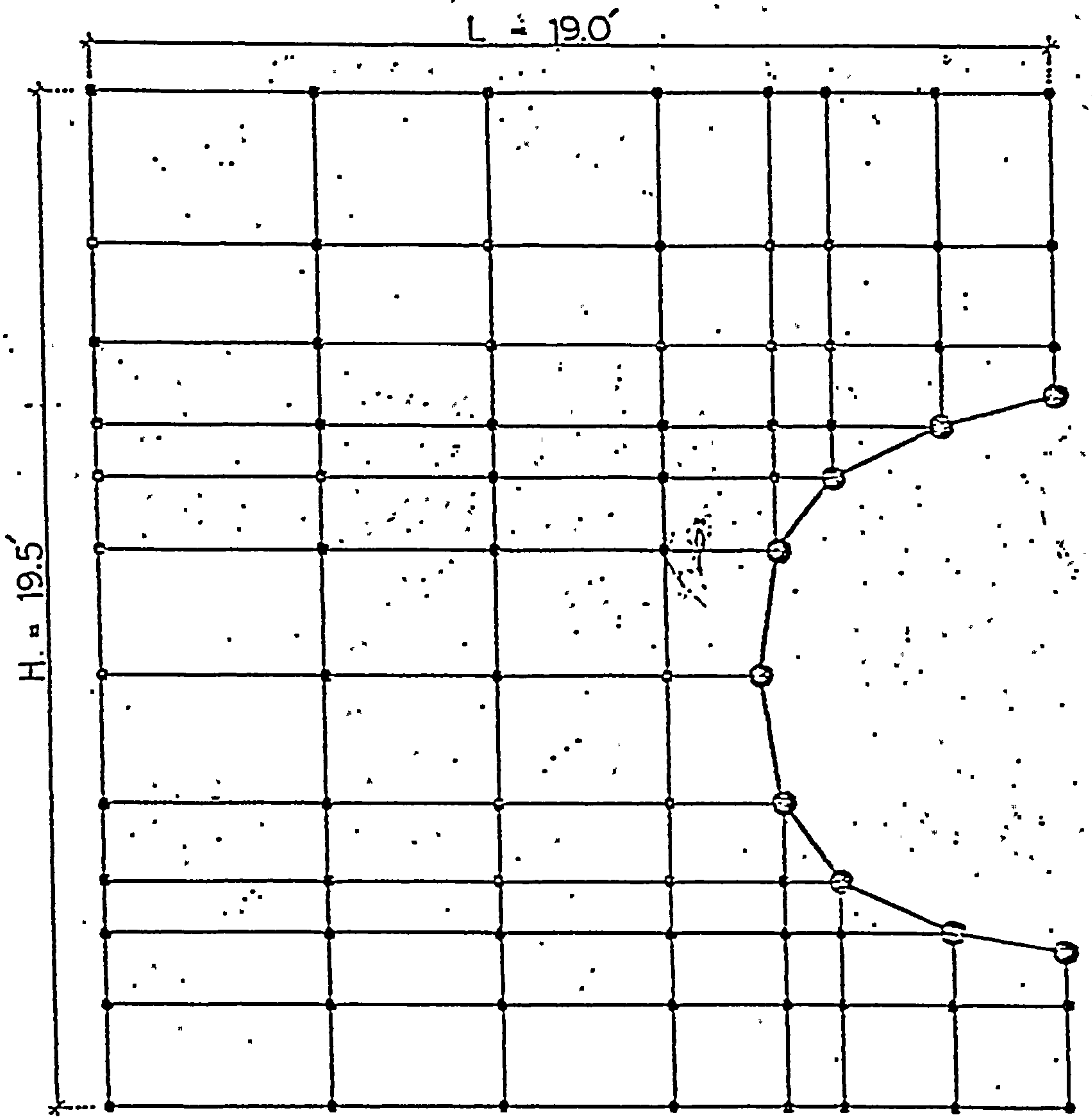
Fig. 1.a



LUMPED MODEL

Fig. 1.b

FINITE ELEMENT MODEL FOR BURIED TANK
(FLUSH CODE)



NODES : 92
SOIL ELEMENTS : 65
BEAM ELEMENTS : 8

Fig. 2

FACTORS OF SAFETY AGAINST COMPRESSION & BENDING

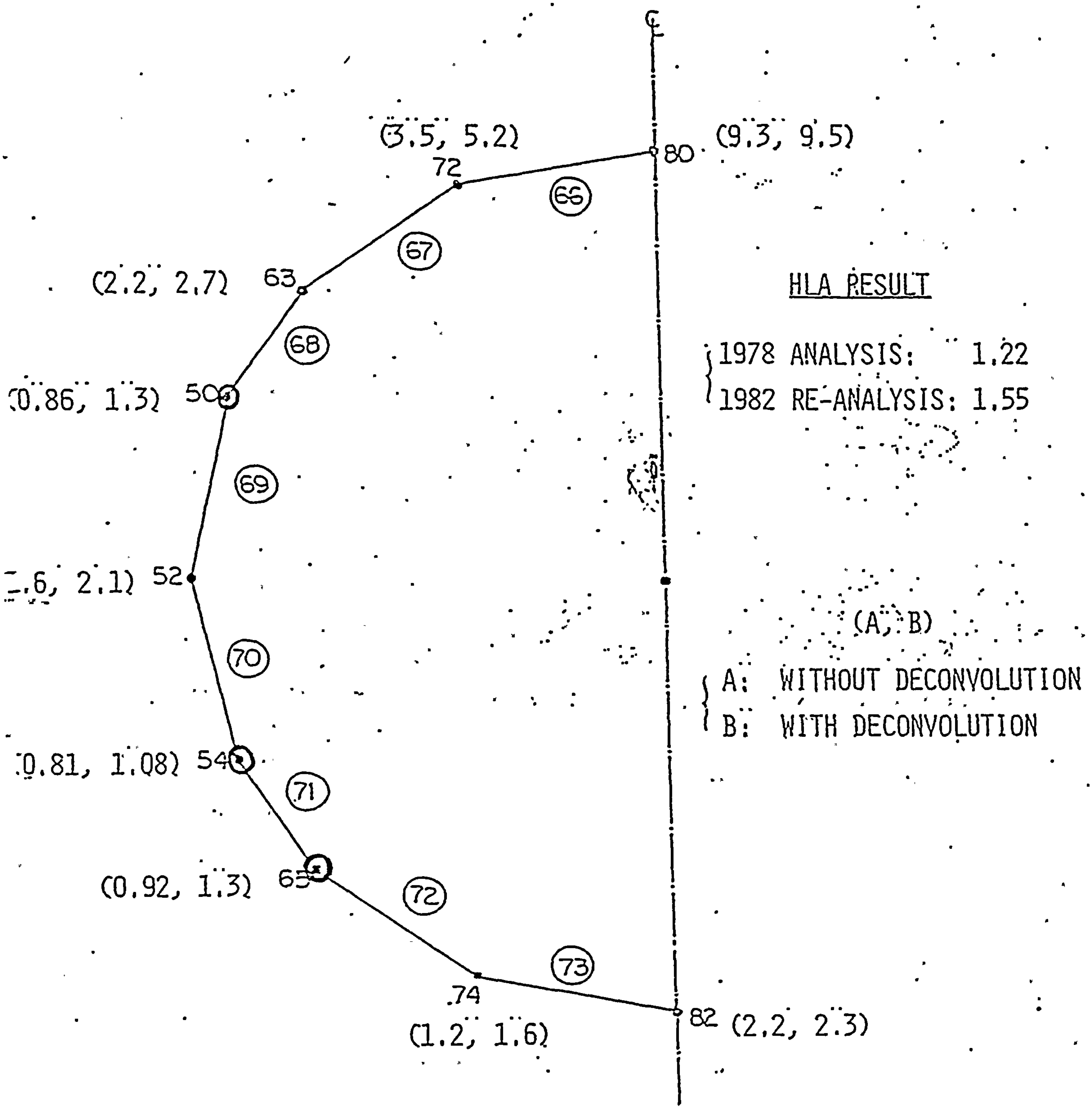


Fig. 3

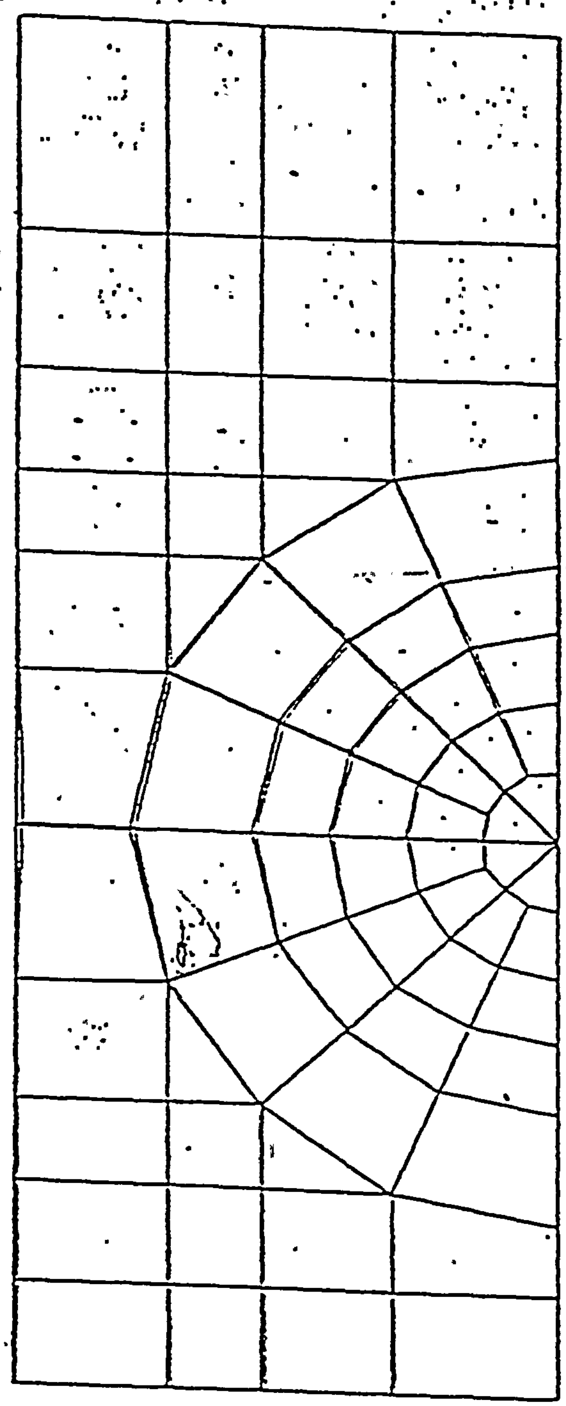


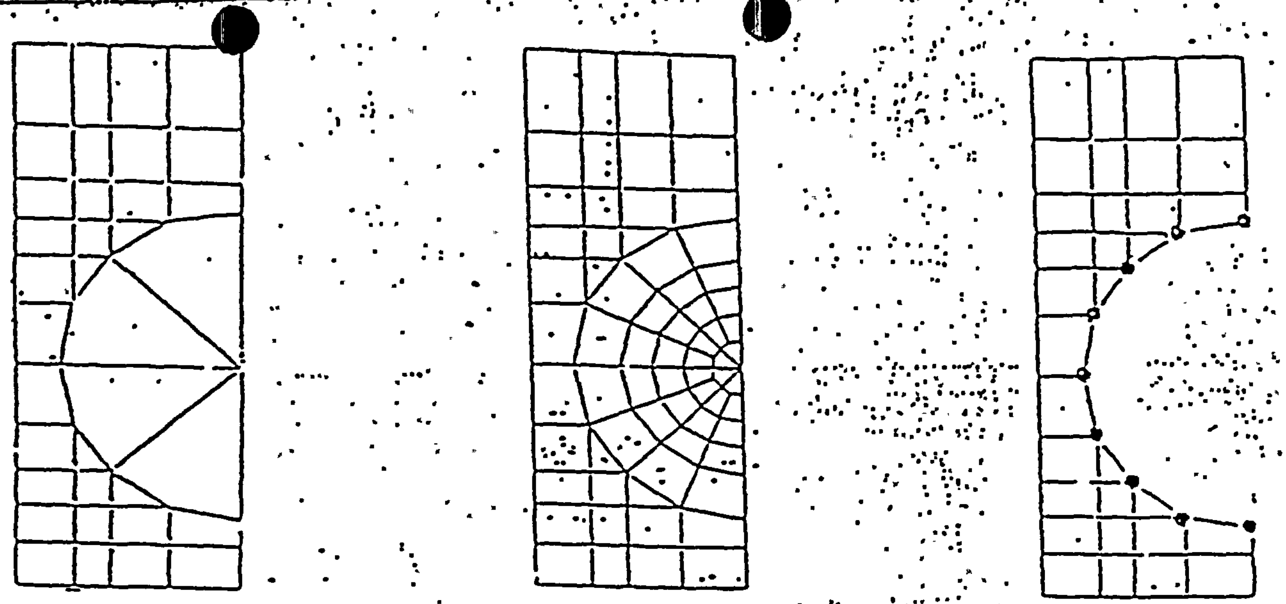
Fig. 4

TABLE 1

COMPARISON OF MOMENT RESPONSES

HARDING AND LAWSON MODEL (FIG. 1a)	BNL LUMPED MASS MODEL (FIG. 1b)
45	588
35	348
11	1133
354	1038
84	199
361	2285
95	2356

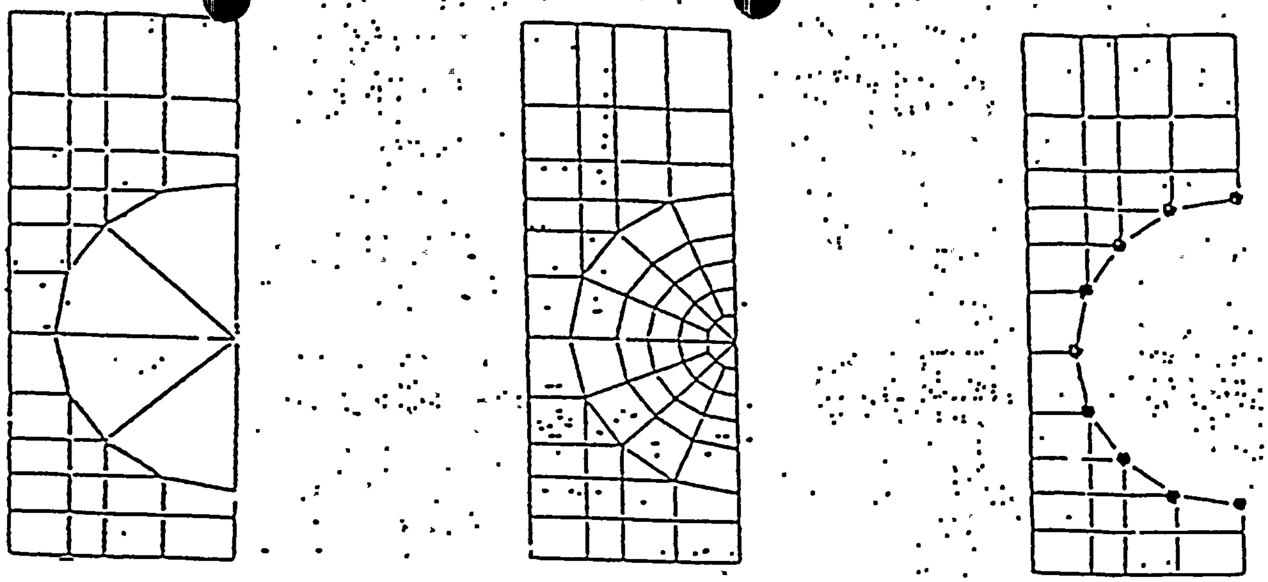
(Units: ft-lb/ft)



NODE	ELEMENT	HLA MODEL	REFINED MODEL	LUMPED MOD
1		0	[illegible] (0)	0
	1			
2		45	347 (863)	588
	2			
3		55	295 (1160)	348
	3			
4		11	788 (1589)	1153
	4			
5		354	629 (600)	1038
	5			
6		84	273 (1225)	199
	6			
7		361	1216 (1711)	2285
	7			
8		95	1669 (2232)	2356
	8			
9		0	0 (0)	0

Moments in ft #
(Horizontal analysis)

[( ) : Y-Y section soil properties]



NODE	ELEMENT	HLA MODEL	REFINED MODEL		LUMPED MOD
1					
	1	9	5	(5)	2
2					
	2	14	9	(17)	5
3					
	3	22	11	(21)	5
4					
	4	19	6	(10)	1
5					
	5	14	4	(3)	5
6					
	6	29	19	(21)	11
7					
	7	39	24	(25)	12
8					
	8	25	9	(9)	4
9					

Axial forces in Kips
(Horizontal analysis)

( ) : Y-Y section soil properties

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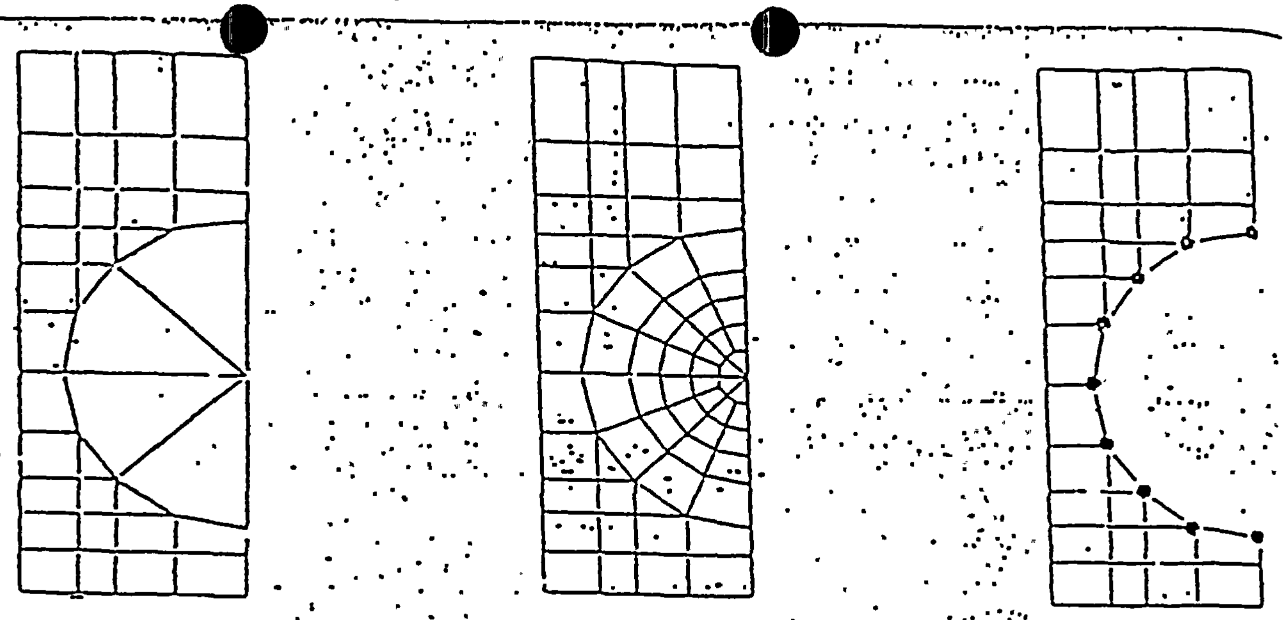

HLA MODEL | REFINED MODEL | LUMPED MO

NODE	ELEMENT	HLA MODEL	REFINED MODEL		LUMPED MO
1					
	1	20	155	(386)	253
2					
	2	38	25	(142)	118
3					
	3	12	238	(232)	180
4					
	4	162	71	(470)	76
5					
	5	136	403	(799)	526
6					
	6	133	458	(259)	1036
7					
	7	127	222	(276)	70
8					
	8	42	746	(998)	1054
9					

Shear forces in #/ft
(Horizontal analysis)

( ) : Y-Y section soil properties