HEA

HARSTEAD ENGINEERING ASSOCIATES • INC.

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DRESDEN 2 & 3

IMPACT EFFECTS ON SPENT FUEL POOL SLAB

1. Introduction

An analysis of a spent fuel storage rack for Dresden Units 2 & 3 was made to determine the effect of the racks on the supporting slab. Using a computer program FRAK, which was developed by Soot & Harstead Associates, P.C., a time history nonlinear analysis was performed.

2.0 Description

2.1 Fuel Storage Racks

The proposed storage is made up of individual racks which are neither connected to the pool structure nor to each other. Under a seismic event the racks would be free to slide and tip independently of each other.

A 9 x 11 rack was selected for this study. The following was calculated:

Approximately fundamental frequency assuming the base is fixed to floor is

74 Hz (vertical)

15 Hz (horizontal in short direction)

While the vertical is close to values presented by the Applicant, our value for horizontal frequency is about 50% greater.

2.2 Fuel Pool

The fuel pool is 41 ft. x 33 ft. in plan with a height of 38.75 ft. The fuel pool floor slab is 6'-3" thick. The walls surrounding the fuel racks are 6 ft. thick. A haunch is provided and extends around the perimeter of

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the slab. The slab is reinforced at the bottom face with #11 @ 6" o.c. each way, two layers. The top face is reinforced with a layer of #11 @ 6" o.c. and #11 @ 18" o.c. in the short direction and one layer #11 @ 12" o.c. in the long direction.

3. Simulated Earthquake Motion

The floor motion used was that which was transmitted by Mr. Owen Rothberg.

4. Time History Nonlinear Analysis.

The computer program was written to the following criteria:

a. Fuel Assemblies inside the tubes may rattle which will influence the structural response.

b. During this analysis the base slab is taken as rigid.

c. When the base seismic inertia forces exceed the base friction force, the rack will slide relative to the spent fuel pool slab. When the base seismic inertial force is less than the base friction force, sliding will cease.

d. When the base overturning moment on the rack due to seismic inertia forces exceeds the base dead load righting moment, the rack will tip. The seismic inertial forces are now determined as an inverted pendulum rather than as a fixed base cantilever. During tipping no sliding was assumed to occur. The rotation of the rack about supports on one side will stop when the uplifted portion of the rack returns to the base slab.

e. When the tipping rack returns in full contact with the floor all the rotational energy is transferred

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to the floor slab. A value is computed in the program for elastic impact. After the transfer of energy rotation when the tipping rack returns to the slab, the rack has no rotational momentum and further rocking ceases.

f. An elastic impact of the racks is assumed on the floor represented by a one degree of freedom system.

g. Vertical seismic motion of the slab was ignored.

5. Results

5.1 Dynamic Analysis

For the purposes of the study the entire pool is assumed to be covered with fuel racks. Results are shown on Attachment 1. Note that if fuel assembly is not considered the impact effects are considerably less.

Comparisons between the applied shears and moments to the allowables show that sufficient reserve capacity exists. See Attachment 2.

6. Conclusions

The analysis was performed with several simplifying assumptions, some conservative - some non-conservative. However, the actual behavior and response was simulated as closely as possible by using a time-history analysis.

The results indicate that the impact effect of the rocking racks on the slab floor is not as great as originally thought. While there may be differences of opinion on methodology, there is agreement on the conclusion that the slab is adequate.

Gunnar A Harstead

GUNNAR A. HARSTEAD

5/19/82.

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PROJECT: DRESDEN
CLIENT:
SUBJECT: COMPUTER PROG. FRAK - RESULTS

PROJ. NO. C- – –
SUBJ. SUBDIV. SHEET
PREP. BY GH DATE
CHCKD. BY DATE

DIRECTION OF E.Q.	FUEL ASSEMBLY IMPACT	COEF. OF FRICTION	MAXIMUM OVERTURNING MOMENT FT-K	EQUIVALENT IMPACT LOAD KSF
NS	YES	0.7	$.232 \times 10^8$	0.760
		.0.2	$.182 \times 10^8$	0.636
	NO	.0.7	$.440 \times 10^7$	0.129
		.0.2	$.680 \times 10^7$	0.236
EW	YES	.0.7	$.174 \times 10^8$	0.707
		.0.2	$.1287 \times 10^8$	0.713
	NO	.0.7	$.853 \times 10^7$	0.182
		.0.2	$.403 \times 10^7$	0.373

ATTACHMENT I

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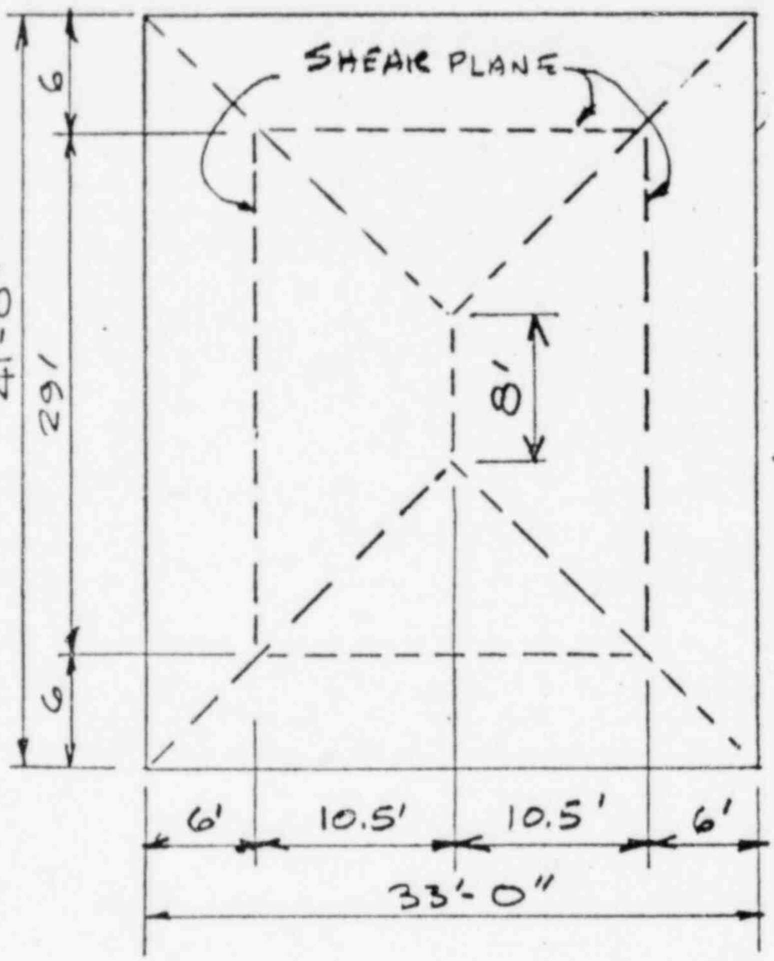
PROJ. NO. C- – –
SUBJ. SUBDIV. SHEET

PROJECT DRESDEN
CLIENT
SUBJECT FUEL POOL SLAB

PREP. BY GH DATE 5-17-82
CHCKD. BY DATE -



REFERENCES
6. Licensee handout 7/13/81
1. Timoshenko, Plates & Shells

LOADING	KSF
D+H+L+E'	6.16 (Ref. 6)
RACK IMPACT	.76
TOTAL	6.92

AREA OF TRAPEZOID

$$A = \frac{8+29}{2}(10.5) = 194.25 \text{ SF}$$

TOTAL SHEAR LOAD

$$V_{TOT} = 6.92(194.25) = 1344.2^{k}$$

$$V_u = \frac{1344.2}{(29)(12)} = 3.86 \ ^{k}/_{IN}$$

ALLOWABLE SHEAR

$$V_c = 2\phi\sqrt{f'_c}\, d = 6.42 > 3.86 \quad \underline{OK}$$

APPLIED MOMENT (Ref 1)

$$M_u = \frac{q_0}{\pi^4\left(\frac{1}{a^2}+\frac{1}{b^2}\right)^2}\left(\frac{1}{a^2}+\frac{\nu}{b^2}\right) = 265.6 \ ^{FTK}/_{FT}$$

ALLOWABLE MOMENT

$$M = 20{,}000 \ ^{FTK}/_{FT} > 265.6 \ ^{FTK}/_{FT} \quad OK$$

ATTACHMENT 2

Licensee handout 7/17/81 mtg

Ref. 6

SUMMARY OF RACK IMPACT ON POOL SLAB

ITEMS		LOAD CASE 1.4D+1.4H+1.7L+1.9E (1)		LOAD CASE D+H+L+E'		REMARKS
		HALF RACKS IMPACT	ALL RACKS IMPACT	HALF RACKS IMPACT	ALL RACKS IMPACT	
Equivalent static uniform load without impact (k/ft^2)		8.29	8.29	6.16	6.16	
Computed equivalent uniform load including rack impact (k/ft^2)	a	14.30	16.78	12.17	14.65	(2)
	b	11.99	14.58	9.86	12.45	(3)
	c	11.43	13.86	9.30	11.73	(4)
Allowable uniform load (k/ft^2)	a	13.04	13.04	13.04	13.04	(5)
	b	13.92	13.92	13.92	13.92	(6)

NOTES:

1. In computing the rack impact load during OBE, it was assumed that 1.9E is equal to E'.
2. Computed using energy balance method considering the strain energy of deformation of the pool slab as a plate. No local deformation of the pool slab under the rack leg and the strain energy of rack was considered.
3. Same as in 2, except that local deformation of the pool slab was considered; strain energy of rack was not considered.
4. Same as in 3, except that strain energy of rack deformation was considered.
5. Slab capacity was governed by shear due to diagonal tension and was computed on the basis of average allowable shear acting on a critical section perpendicular to plane of the pool slab and located so that its perimeter is a distance d (effective depth of slab) from edge of the pool slab.
6. Same as Note 5 except that f'_c for concrete was increased by 15 percent due to aging.