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Seismic Analysis for a Crane System

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1. Introduction

The operation bridge used for an open-pool type research reactor is a crane system with a working deck for the handling of in-pool parts such as fuels, reactor components and reactor utilization facilities. The operation bridge allows operators to access the top of the reactor in the reactor pool and the fuel storage racks in the service pool. The operation bridge contains an operating platform mounted on a truck travelling on rails. Upright members are mounted on the truck to support the upper structure and two hoist monorails. The operation bridge consists of two hoists, upper girder frames, legs, cables, saddle frames, upper deck frames, lower deck frames, and the ladder.

Static and dynamic analyses are performed to evaluate the structural integrity for the operation bridge for the required design loadings. The response spectrum analysis is employed as a dynamic analysis method.

2. Methods and Results

2.1 FEM Model

The operation bridge consists of the structural steel beam and the plate. An analysis model using the ANSYS Code is shown in Fig. 1. Beam element (BEAM 188) is used for modeling. The weights of the plate and hoists are applied to the beams as the concentrated mass. The dimensions of the beams and boundary conditions are as follows.

- Rectangular Beam : 328x250,13 t (mm)
- H-beam : H250x125x6/9t
- H-beam : H200x100x5.5/8t
- H-beam : H100x50x5/7.5t
- Pipe : Ri=90 mm, Ro=102 mm

Table 1. Boundary conditions of Operation Bridge

Node	Translation			Rotation
	x	y	z	
68	Fixed	Fixed	Fixed	All nodes are considered to be free to rotation.
28	Free	Fixed	Fixed	
149	Fixed	Fixed	Free	
109	Free	Fixed	Free	

2.2 Material Properties

All structural steel shall conform to ASTM Specification A36 and the mechanical properties are presented in Table 2.

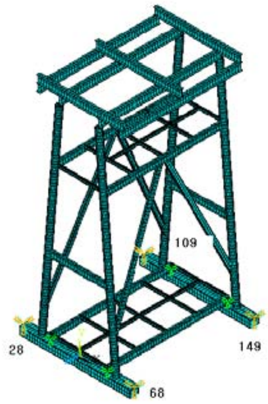

Fig. 1 ANSYS model of Operation Bridge

Table 2 Material Property of ASTM A36

Material Property	ASTM A36 (SS41)
Modulus of Elasticity	2.034E+11 N/m^2
Poisson's Ratio	0.3
Mass Density	7850 kg/m^3
Yield Strength (σ_y)	248 MPa
Tensile Strength (σ_u)	400 MPa
Allowable Stress (σ_a)	0.6σ_y (149 MPa), 0.9 σ_y (223 MPa)

2.3 Design Requirements of Code

The operation bridge is designed in accordance with CMAA 70 [1] and ASME NOG-1 [2].
The operation bridge shall be designed to resist loading generated by the SSE (Safe Shutdown Earthquake)[3].

Table 3. Load Combination and Design Limit

	Combinations	Design Limits(Tension)
Static	D +L	0.5 σ_y
Static+Dynamic	D + L + SSE	0.9 σ_y

In Table 3, σ_y is the yield stress of the given material.

In case of combining the axial tension and the bending, the members shall satisfy the requirement of the following equation.

$$\frac{\sigma}{\sigma_a} + \frac{\sigma_{bx}}{\sigma_{abx}} + \frac{\sigma_{by}}{\sigma_{aby}} \le 1.0 --- (1)$$

Where, σ_a and σ_{ab} are allowable axial and bending stresses, respectively.

2.4. Analysis Results

2.4.1 Static Analysis

When the hoists are located at the center of the upper girder frame, the results of the static analysis are shown in Fig. 2 and Table 4.

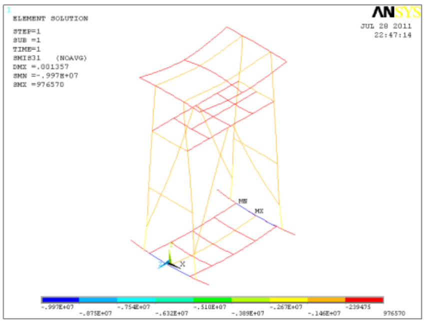

Fig. 2 Distribution of axial stress(Static Analysis)

Table 4. Results of Static Analysis

Element (Node)	σ_x (MPa)	σ_{bx} (MPa)	σ_{by} (MPa)	τ_{xy} (MPa)
13 (24)	0.154	-0.091	6.811	0.250
33 (62)	0.154	-0.086	6.643	0.260
73 (145)	0.155	-0.084	6.655	0.260
53 (103)	0.155	-0.089	6.826	0.250
749(643)	-0.410	-0.542	0.947	0.150
802(1281)	-0.410	-0.408	1.479	0.340
838(1349)	-0.410	1.491	1.801	0.380
758 (687)	-0.401	1.652	1.262	0.190

In Table 4, σ_x = Axial Stress, σ_{bx} = Bending Stress in x direction, σ_{by} = Bending Stress in y direction, τ_{xy} = Shear Stress by Shear Force + Shear Stress by Torsion

2.4.2 Modal Analysis

When the hoists are located at the center of the upper girder frame, the natural frequency of the operation bridge is as follows.

Mode	Freq.(Hz)
1	4.9242
2	5.52412
3	7.63446
4	9.23039
5	10.3598

2.4.3 Seismic Analysis

When the hoists are located at the center of the upper girder frame, the results of seismic analysis (distribution of axial stress, bending stress and shear stress) are shown in Fig. 3 and Table 5.

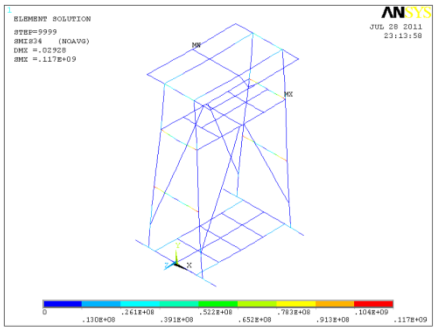

Fig. 3 Distribution of bending stress (SSE, 7% Damping)

Table 5. Results of Seismic Analysis

Element (Node)	σ_x (MPa)	σ_{bx} (MPa)	σ_{by} (MPa)	τ_{xy} (MPa)
13 (24)	0.922	11.63	13.57	1.27
33 (62)	0.955	10.12	13.41	1.19
73 (145)	0.958	1.27	13.51	1.13
53 (103)	0.929	1.13	13.61	1.28
749(643)	0.877	23.77	115.72	4.54
802(1281)	0.954	23.62	116.88	4.78
838(1349)	0.972	25.96	117.38	4.76
758 (687)	0.828	28.24	116.38	4.65

2.4.4 Load Combinations

When the hoists are located at the center of the upper girder frame, result values for the static and the seismic analysis are smaller than the design limit. Also, these satisfy the equation (1) in case of combining the axial tension and the bending. But, these do not satisfy the equation (1) when hoists are located respectively at the center and the end of the upper girder frame.

3. Conclusions

When hoists are located respectively at the center and the end of the upper girder frame, the results values for the seismic analysis do not satisfy the requirement of the limit of Combined Stress (ASME NOG-1, Section 4320). Therefore, the members of the operation bridge must be reinforced.

Acknowledgements

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REFERENCES

[1] CMAA 70 Specification for electric overhead travelling crane.
[2] ANSI/ASME NOG-1 Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder).
[3] JR-070-KP-417-001, “Seismic Design Guide for JRTR”, Korea Atomic Energy Research Institute.