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Structural Integrity Analysis of CEA Change Platform

Jin Hwa Shin, Byeong Taek Park, Jun Beom Park, Jong Ha Jung, Byeong Wook Noh
Doosan Heavy Industries & Construction Co., Ltd, Nuclear Power Plant Reactor Design Team
jinhwa.shin@doosan.com

1. Introduction

The Control Element Assembly Change Platform (CEA CP) is similar to a gantry crane. The CEA CP for Shin-Kori units 3 and 4 (SKN 3&4) consists of a bridge, which spans the reactor cavity pool and a gantry superstructure mounted on the bridge. The structure is approximately 8.8 m wide, 4.9 m long and 10.6 m high. The gantry superstructure supports one ton capacity hoist trolley and the bridge supports the In Core Instrumentation (ICI) retrieval cart which moves along the bridge.

This paper presents the dynamic and structural analysis of CEA CP which is greater than that of the previous nuclear power plants to verify the structural integrity under the application of the earthquake spectrum. The analysis have been performed using the three orthogonal SSE response spectrum for SKN 3&4 which shows much higher acceleration value than OPR-1000 Plants. In addition, the analyses are performed by 3-dimmensional finite element analysis using ANSYS software [1].

2. Seismic Analysis

2.1 Finite Element Modeling

The CEA Change Platform was modeled as a finite element model consisting of ANSYS BEAM 4 (structural beam element), MASS 21 (structural mass element) and COMBIN 14 (spring-damper element). Material and section properties were determined by ten basic beam section types, four types of mass and spring constant for hoist. Figure 1 shows the CEA Change Platform FE model.

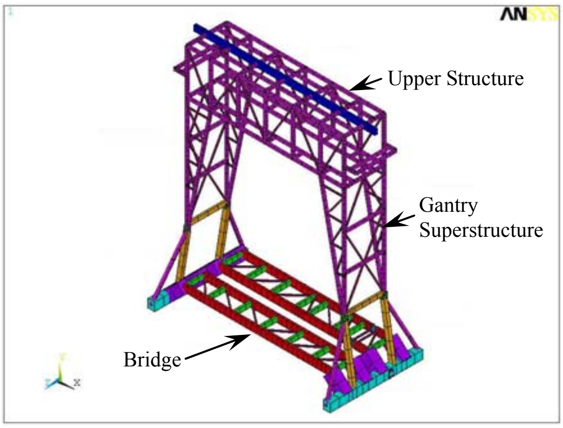

Figure 1 CEA Change Platform FE Model

2.2 Analysis condition

The ICI module was parked on the side of wal

The gantry hoist could be situated at three positions such as side, midspan and the 1/4 of gantry hoist rail. In the seismic analysis, the hoist is positioned at the maximum or the minimum elevation.

Dead loads are imposed by 1.0g vertically downward gravity. Dead loads include all weight of equipment and accessory. Live loads include ICI windup reel load (363 kg) and hoist carrying load (1000 kg).

The analysis was performed to obtain the seismic response of mathematical model using the standard equations of motion for damped linear system. The matrix equations were used to find out the natural frequencies, the corresponding mode shapes of the system and the response spectrum analysis.

The maximum response in each of the modes is calculated base on the spectra (accelerations) in the X, Y, and Z directions by the program. Figure 2 shows one of the response spectra used in this analysis. It represents the spectrum for the north-south direction (X direction).

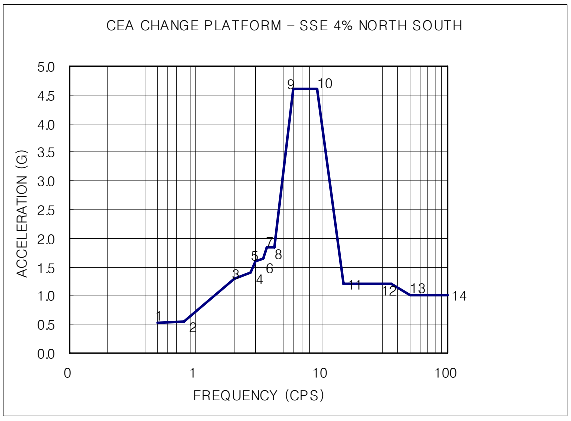

Figure 2 Reference response spectra

2.3 Seismic Evaluation

As the first step, modal analysis was carried out to perform seismic analysis. The first ten modal frequencies for the CEA Change platform are listed in Table 1. The selected modes represent the effective mass ratio more than 90% of total mass. As shown Figure 3, the 2^{nd} mode of 4.369 Hz natural frequency is most important, because the participation factor of this mode is the highest value.

Table 1 Modal Frequencies

Mode sequence No.	Frequency (Hz)	Mode sequence No.	Frequency (Hz)
1	3.922	6	14.817
2	4.369	7	16.613
3	6.876	8	16.251
4	8.639	9	17.593
5	9.739	10	18.964

* Effective mass / Total mass = 93.6 %

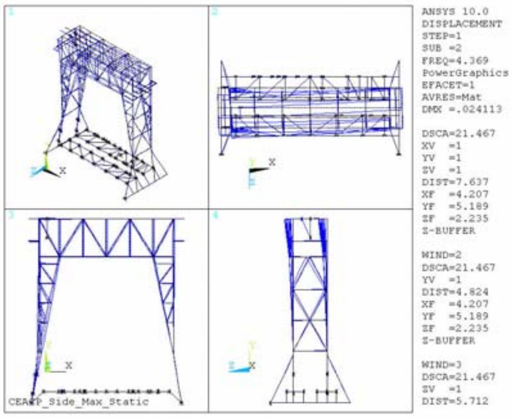

Figure 3 Mode shape at 4.369 Hz

The seismic analysis is performed for all the cases of parking and operation. The allowable stresses are the normal limits of stress as defined KEPIC MCN 2320. The acceptance criteria used for the SSE seismic load cases are defined as:

$$\frac{\sigma}{\sigma_a} + \frac{\sigma_{by}}{\sigma_{aby}} + \frac{\sigma_{bz}}{\sigma_{abz}} \le 1.6$$

σ_a: Allowable axial stress
σ_{aby}: Allowable bending stress in Y direction
σ_{abz}: Allowable bending stress in Z direction

The maximum values of the interactions for the combined XYZ (X and Z horizontal, Y vertical) seismic and operating loads are listed in Table 2 for Operating plus SSE condition. The calculated values for the combined stress equation for three major structures under seismic and operating load are lower than the acceptance criteria.

Table 2 Maximum beam interaction summary of operating plus SSE condition

Location	Stress [MPa]			Comb. Stress Eq.	Allow-able
	σ	σ_{by}	σ_{bz}		
Bridge	12.8	100.0	49.8	1.1	1.6
Gentry Structure	12.3	116.7	69.1	1.5	1.6
Upper Structure	109.7	87.2	9.4	1.3	1.6

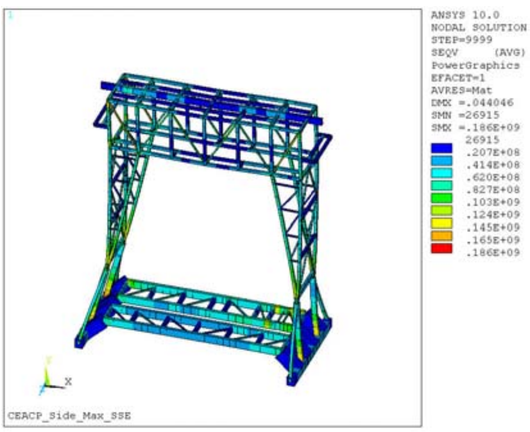

Figure 4 Distribution of the von Mises stress on CEA Change Platform

3. Detail Stress Analysis

The welded and bolted joints are investigated for the safety. The allowable stress for fillet welds under shear load is defined as:

$$\sigma_{aw} = 0.3\sigma_t \times 1.5(\text{seismic factor})$$

σ_{aw}: Allowable stress in weld
σ_t: Tensile strength

Table 3 The summary of result – Welded joints

Item	Weld leg [mm]	Combined weld stress/unit weld length [MPa]	Allowable Stress [MPa]
Square tubing on gantry end	6	135	217
Brace on gantry end	6	29	217

And the allowable stress for bolts is based on the KEPIC MCN 2315 and 2323. The lower value between following two equations is adopted as the tensile allowable stress:

$$\sigma_{at} = 0.5\sigma_t$$
$$\sigma_{at} = 0.6\sigma_y R - 1.6\tau$$

σ_{at}: Allowable stress in tension
σ_y: Yield stress

Where R = 1.5 for SSE condition.

Shear allowable stress is defined as:

$$\tau_a = 0.26\sigma_t$$

Table 4 The summary of result – Bolted joints

Connection item	Used Bolt	Actual stress [MPa]		Allowable Stress [MPa]
between gantry and Bridge end trucks	M20 (KS F10T)	Shear	31	258
		Tensile	250	490
between upper structure and gantry end	M20 (KS F10T)	Shear	11	258
		Tensile	127	490
Hold down bracket (Bridge)	M24 (KS F10T)	Shear	138	258

4. Conclusions

The structural analysis of CEA Change Platform has been carried out to verify the structural integrity. After performing the modal analysis, ten significant modes, which represent the effective mass above 90% of total mass, are selected for the seismic spectrum analysis. The results of seismic analysis show that all structures meet the combined stress equation in KEPIC MCN 2320. In addition, the detailed stress evaluation for welded and bolted joints has been investigated. As a result of evaluation, the structural integrity of CEA Change Platform has been verified.

References

[1] ANSYS Finite Element Computer Code & Manual
[2] Design Specification for Fuel Handling System Equipment
[3] Korea Electric Power Industry Code (KEPIC) MCN, 2000
[4] Regulatory Guide 1.92, Combining modal responses and spatial components in seismic response analysis, Rev.2
[5] Regulatory Guide 1.61, Damping values for Seismic design of nuclear power plants, Rev.1