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Comparison of Various Response Spectrum of Nuclear Power Plant at Chashma Site

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Abstract

UBC-97, USNRC, chines origin code GB50011-2011 and site response spectrum was used to make comparison between them for Chashma site and most conservative one was selected and the USNRC was the most conservative one. The dynamic analysis of CHASNUPP-2 containment building was performed using SAP-2000 for dead load, live load (crane), pre stressed loads, wind load, temperature load, accidental pressure during LOCA, earthquake loads and the conservative response spectrum. After applying selected response spectrum on model, detail comparison was made against area of steal calculated from the analysis and the actually provided. Then prepared curve of area of steal vs. g value which shows that if the particular site was design on that spectrum that much steel needed for structural integrity.

Keywords: Response Spectrum; USNRC; LOCA; Area of steel; Structure integrity

1. Introduction

Earthquake forces result from the vibratory motion of the ground on which the structure is supported. The vibratory motion of the ground sets up inertia forces both vertically and horizontally. The vertical forces are taken as 2/3. because of self weight of building.

The great interest Earthquake forces result from the vibratory motion of the ground on which the structure is supported.

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The vibratory motion of the ground sets up inertia forces both vertically and horizontally, but it is customary to neglect the vertical component except for cantilevers, since most members have adequate reserve strength for vertical loads because of safety factors specified for gravity loads. The horizontal forces, equal to mass times acceleration, represent the inertia forces occurring at the critical instant of maximum deflection and zero velocity during the largest cycle of vibration as the structure responds to the earthquake motion.

The CHASNUPP-2 is situated at Chashma site in the south of Mianwali, near the Chashma Barrage. It is a single-unit of 325 MWe Class and includes a two loop pressurized water reactor (PWR) nuclear steam supply system (NSSS) furnished by China National Nuclear Corporation (CNNC). The seismic criteria used to design the structures and equipment in the plant is considered, horizontal ground acceleration for the Operating Basis Earthquake (OBE) was 0.125g and for the Safe Shutdown Earthquake (SSE) it was 0.25g whereas vertical ground acceleration for OBE is 0.0833 g and for SSE it is 0.1667g.

The soil of Chashma is stiff soil known as soil type ‘D’ according to UBC-97 soil characterization. The Chashma is located in zone 2B according to seismic zoning of BCP-07. Damping ratio is taken as 5% [6].

After the October 2008 earthquake in Pakistan special consideration was paid on the dynamic design of structure. Earthquake motion causes vibration of the structure leading to inertia forces. Thus a structure must be able to safely transmit the horizontal and the vertical inertia forces generated in the super structure through the foundation to the ground. Hence, for most of the ordinary structures, an analysis and design must be performed to demonstrate that the applicable stress, strain, and deformation limits are satisfied ensuring that the structure has adequate lateral load carrying capacity.

For the purpose of seismic analysis and design of a nuclear power plant structure, the representative maximum response of interest for design (e.g., displacement, acceleration, forces, shear, moment and stress) can be obtained by combining the corresponding maximum individual modal responses derived from the response spectrum method. While selecting the response spectrum we will use best suited with particular site.

As no no particular response spectrum was available for Chashma site so we have to choose tha**t** will be most conservative one.

2. Design Response Spectrum

A response spectrum is a plot of maximum response of systems to a given ground acceleration versus period. Response spectrum graphs are generated by numerical integration of actual earthquake records to determine maximum values for each period of vibration. Response spectrum is also calculated by using specific code for particular site. Response spectra are very useful tools in earthquake engineering for analysing the performance of structures in earthquakes. UBC 1997

According to UBS design response Spectrum is an elastic response spectrum for 5 percent equivalent viscous damping used to represent the dynamic effects of the Design Basis ground motion for the design of structures in accordance with sections 1630 and 1631 of UBC [1]. This response spectrum may be either a site-specific spectrum based on geologic, tectonic, seismological and soil characteristics associated with a specific site or may be a spectrum constructed in accordance with the spectral shape using the site specific values of Ca and Cv and multiplied by the acceleration of gravity, 386.4 in/sec2 (9.815 m/sec2).

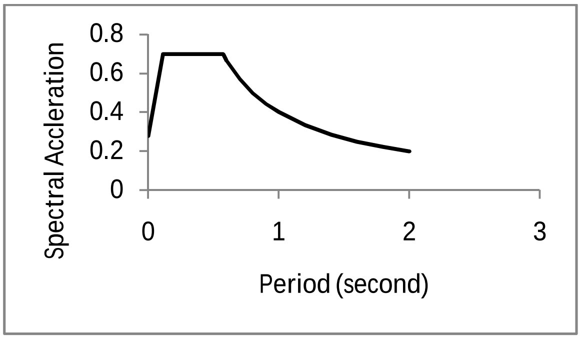

Figure 1: Calculated UBC-97 Spectrum

US Nuclear regulatory Guide 1.60

This guide describes a procedure acceptable to the AEC Regulatory staff for defining response spectra for the seismic design of nuclear power plants.

Design Response Spectra for each of the two mutually perpendicular horizontal axes are shown in the graph. Design response spectra in this guide correspond to a maximum horizontal ground acceleration of 1.0 g [2].

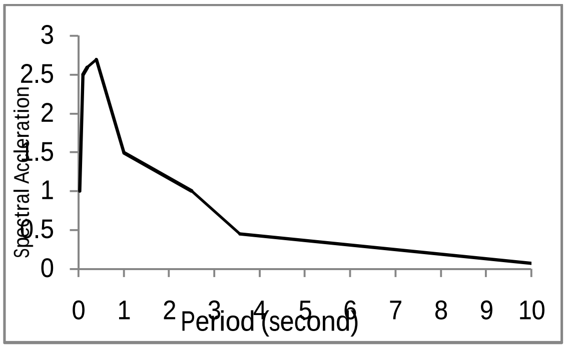

Figure 2: Calculated USNRC Spectrum

Chinese Origin Code GB50011-2011

The Chinese origin response spectrum using GB50011-2011 guide for Chashma site is show below [3].

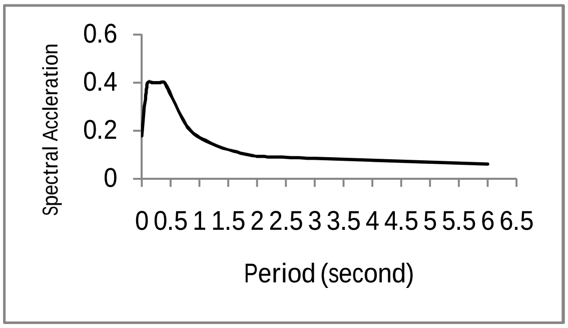

Figure 3: Calculated Chinese origin RS.

Site response Spectrum Site response spectrum for Chashma site is shown below [4].

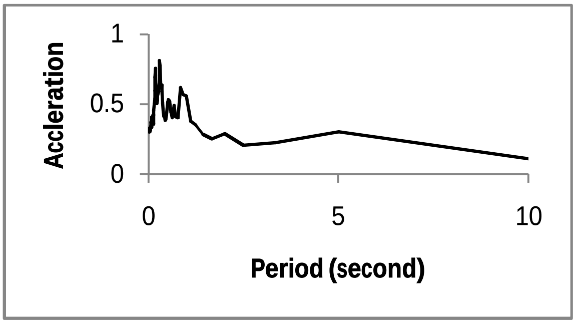

Figure 4: Site Response Spectrum

3. Comparison of Response Spectrum

Comparison of uniform building code of Pakistan, US nuclear regulatory commission guide, Chinese origin code and site response spectrum for Chashma site are shown in the graph below.

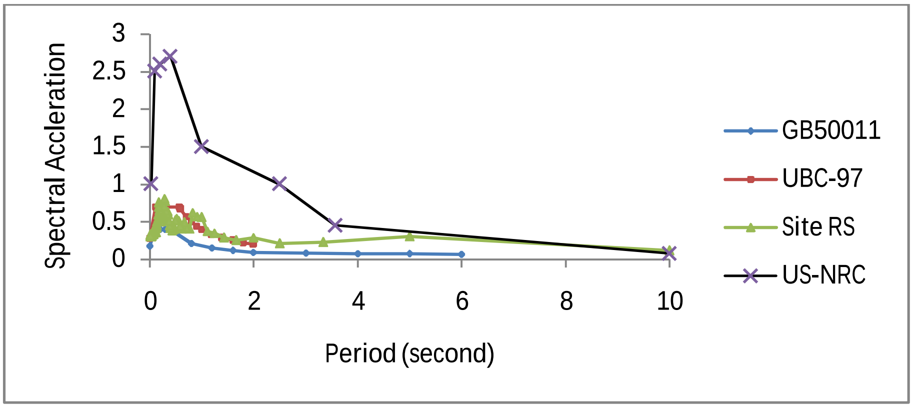

Figure 5: Comparison of Response Spectrum

4. Containment modeling in SAP-2000

The containment houses the entire pressurized water reactor, steam generators, reactor coolant loops, and portions of the auxiliary and engineered safety features systems. It ensures that leakage of radioactive material to the environment does not exceed the acceptable dose limit.

The containment is a pre-stressed concrete shell structure composed of a cylinder with a shallow dome and is founded on a flat foundation base slab. The entire structure is lined on the inside with steel plate that acts as a leak tight membrane. The cylindrical portion of the containment is pre-stressed by a post-tensioning system consisting of horizontal and vertical tendons. There are three buttresses equally spaced around the containment and each horizontal tendon is anchored at buttresses 240 ℃ dome post-tensioning system is made up of three groups of tensions oriented 120 ℃ to each other and anchored at the vertical face of the dome ring girder [6].

SAP-2000 structure analysis software was use to analyze the containment against different loading and saw the behavior of containment against g value [5]. The containment was analyzed against 12 loading combinations of Dead load, Live load, Wind load, Temperature load, Accident Pressure load, Prestress load and Earth quake load. After applying the entire above mention load and the most conservative response spectrum (USNRC) on the containment modal of C-2 twelve loading combination are applied on the modal and analyze for each one of them. Then the most severe loading combination is taken for analysis purpose.

Severe loading combination for model analysis is = 1.0 D + 1.0 L + 1.0 F + 1.0 Ess + 1.0 Pa+1.0 Ta +1.0W.

The deformed shape stress variation diagrams for severe loading combination are shown in the figures below.

Figure 6: SAP-200 Model deformed shape against severe load combination

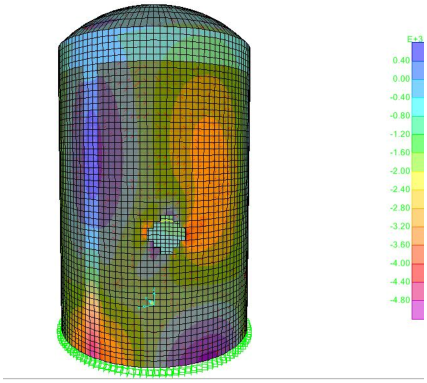

Figure 7: Severe loading stress diagram

5. Analysis

The containment cylinder wall shells are divided into 3 parts, i.e. the base part, middle part and the top part. We select a element from each part and the dome, list the combination results. Thus we can compare the internal forces under different combinations and find the control combination. We select following Elements: No. 14341 at bottom, No. 14455 at middle, No. 17392 at top, no. 20193 at dome.

For Analysis we are consider containment wall as column if factored axial compressive force on the member shall not exceed (**$A_g f'_c / 10$**) [7]. Design curves have been prepared by ACI. They cover most frequent practical cases i.e. symmetrically reinforced rectangular and square columns and circular spirally reinforced col. A Graph representative of column design chart is shown below [8]. Families of curves are plotted for various values of ϱg. They are used in most cases in conjunction with families of radial lines representing different eccentricity ratio, e/h. Charts such as these, permit the direct design of eccentrically loaded column throughout the column range of strength and geometric values.

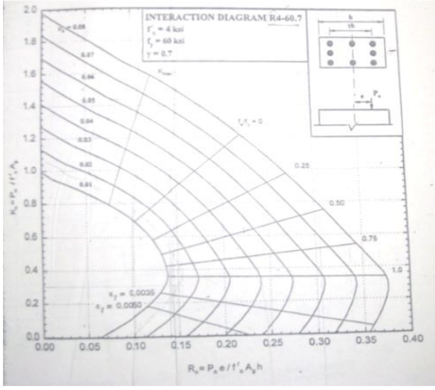

Figure 8: Interaction diagram (Design Aid)

After applying check for axial or compression member area of steel calculated at each selected point and compare them with actually provided.

f 'c = 4000 psi = 27578.8 KN/m2
h = 39.36 in = 1 m
Ag*fc/10 = 2757.88

F11 max= 6808.61 KN > 2757.88 Design as axial member

M11max= 69.63 KNm
Pn= 9726.586 KN = 666.627 kip/ft.
Mn= 99.47143 KNm = 73.34466 kip.ft
E = 0.010227 m = 0.402525 in <10
ϒ= 0.720528
Kn= 0.352847
Rn= 0.14203
Using Design Aid
ρg= 0.01
Ag= 15.4921 in2 Designed As min= 5.164032 ok
2 #10 @6in c/c Actual provided
As= 16.93 in2 > Designed…….. OK

Similarly Element No. 14455 at middle, No. 17392 at top, no. 20193 at dome are check against area of steal provided and comes out to be safe.

To analyze the behavior of containment against increasing frequency of earthquake we are changing the scale factor from 0.2g to 1g. 1g is the maximum limit because USNRC spectrum is valid up to 1g. The results are shown in the table below.

Table 1: Area of steel Vs g value

S.NO	g Value	Area of steel
1	0.2	15.4921
2	0.25	16.2667
3	0.3	18.5905
4	0.35	19.3651
5	0.4	20.1397
6	0.45	20.9143
7	0.5	21.6889
8	0.6	23.2381
9	0.7	24.7873
10	0.8	26.3365
11	0.9	27.8857
12	1	29.4349

The plot of these values is shown in the graph below.

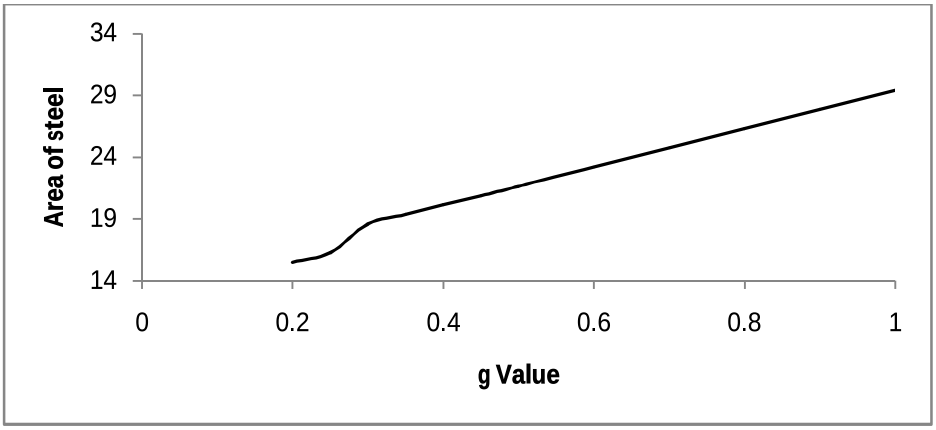

Figure 9: Behavior of steel against g value

6. Conclusions

USNRC spectrum is the most conservative one and is only depend on damping ratio not very much on other property and very high factor of safety is incorporated. That's why it is universally applicable. Due to its high factor of safety it is applicable for nuclear grade buildings not for other buildings. UBC-2007 is also satisfactorily safe but FOS is not very high but it is applicable safely for other building in that area. Site response spectrum for the site is not considered because not enough data is available for the site.

The containment building is safe against severe load condition. The behavior of steel against g value determined from analysis. By increasing the g value for design of containment more steel will required to resist that force as a result of it. From graph it is clear that up to 0.3g the present Containment is safe against that value. After 0.3g there is abrupt change in area of steel and for structure to resist that more steel will be provided. Under low Earthquake area of steel required for structure to give strength is low. But as the earth quake intensity increases area of steel required to provide the strength or prevent yielding is high.

So at high earthquake we either increase thickness of building to increase self weight or use high yielding strength steel or provide high area of steel as show in the graph.

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References

UBC (1997), "Uniform Building Code 1997", International Conference of Building Officials, Whittier, California, USA.

U.S.Nuclear Regulatory Commission, Regulatory guide1.60, Design Response Spectra for Seismic Design of Nuclear Power Plants, USNRC, U.S.A, 1973.

National Standards of the People's Republic of China GB50011-2001.

A. K. Gupta, Response Spectrum Method in Seismic Analysis and Design of Structures, CRC Press, 1992.

Computers and Structures, SAP 2000 Software, University Avenue Berkeley, California, USA, 2000.

Pakistan Atomic Energy Commission, Final Safety Analysis Report of CHASNUPP-1, PAEC, Pakistan, 1998.

ACI-ASME Committee 359,ACI Standard Code for Concrete Reactor Vessels and Containments (ACI 359-80), 2007.

ACI Special publication SP-7 by Everard and Cohen, 1964, pp. 152-182.