ANTI-EARTHQUAKE STRUCTURAL DESIGN FOR CSNS BEAM DUMP*

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Abstract

To ensure the beam dump shield iron can resist the damage of earthquake and maintain the normal protective capability, anti-earthquake design was carried out in this paper. The parts for seismic resistance were designed according to the feature of foundation building. The force model was reached through the analysis of seismic load. The structure dimension was decided on the basis of the theory of strength. A pre-buried plate with hooks was achieved and the force model was simplified as fixed end. The minimal diameter of hook showed 30mm. The fixing device with plate decreases the precision requirement of foundation building and can be used to fix the shield iron to resist the earthquake.

PREFACE

CSNS is the abbreviation of China Spallation Neutron Source. It is one of the most important national building for Large Scientific Devices during the eleventh 5-year plan [1]. Beam dump is an important part in CSNS device, which is composed of shield steel plates, concrete shield and vacuum boxes to lead to the dump beam. For the serious damage of earthquake, the effect of earthquake on shield steel plates should be considered when installing and fixing the shield steel plates.

STRUCTURAL DESIGN

In order to make the shield steel plates have the capability to resist the earthquake, they must be joined with the foundations firmly.

The fixing part will be used for the joint of the shield steel plates and the foundations. Considering the low position precision of concrete casting, we design the fixing part with 4 L style hooks to be casted in the foundation, which can increase the forcing area. Meanwhile, a small plate was distributed on the ground to join the shield steel plates. The technology of plug welding will be used to join the shield steel plate and the fixing part. Plug welding method lets two plates overlap together with a hole in one of the plates. The welding material is melt to fill the hole and form the welding layer [2]. The structure of the fixing part and its installing form in the foundations are shown as figure 1.

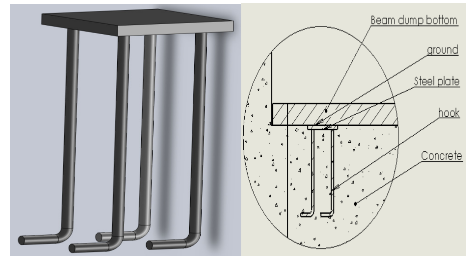

Figure 1: Structure of Fixing Part and its Installation.

FORCE ANALYSIS

Load of the Fixing Part from Earthquake

The earthquake caused by the movement of the small independent landmasses is the result of movement to east or west under the earth rotation on its own axis and the gravity of the small landmasses. The damage of earthquake comes from the force of the earth inertia. Things on the earth revolve with the same velocity of the earth in usual condition. But when earthquake happens, the strong inertia force is formed by the obstruction of small landmasses [3-4].

According to Code for Seismic Design of Buildings (GB50011-2010), we get an acceleration table for earthquake. It is shown as table 1.

Table 1: Acceleration Table for Earthquake

Grand	6	7	8	9
Acc	0.05g	0.1g	0.2g	0.4g

We suppose the beam dump can undergo Ⅷ earthquake to the maximum. So we set the acceleration α as 0.2g [5]. The fixing part will undergo the action of earthquake force from horizontal and vertical directions. The force unit can be reached according to the action style of force. The drafts of force action and force unit are shown as figure 2.

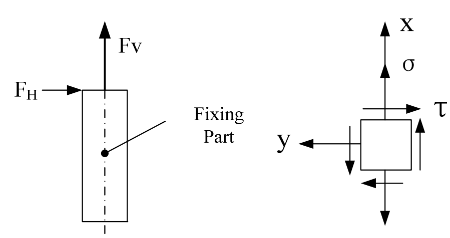

Figure 2: Draft of force action and unit for fixing part.

Table 2: Diameter Calculation Table for Hooks of Fixing Parts

Beam Dump	Quality (t)	α	F_V (N)	F_H (N)	[σ] (MPa)	Number	Min d (mm)	Set d (mm)
L-DUMP-B	102	1.96	199,920	199,920	157	4	20.04	30
I-DUMP	74	1.96	145,040	145,040	157	4	17.07	30
R-DUMP	402	1.96	787,920	787,920	157	8	28.13	30

Strength Calculation

Horizontal force makes shearing action and vertical force makes stretching action to the fixing part. According to the strength calculation rule and some relating theory [6], the calculation is shown as below formula (1)~(2).

$$\tau = \frac{F_H}{A} = \frac{4F_H}{\pi d^2} \quad (1)$$

$$\sigma = \frac{F_V}{A} = \frac{4F_V}{\pi d^2} \quad (2)$$

Stress for the force unit can be reached according to the coordinate of figure 2. They are shown as formula 3.

$$\sigma_x = \sigma,\ \sigma_y = 0,\ \tau_{xy} = \tau \quad (3)$$

The plane stress calculation formula is shown as below.

$$\sigma_{max} = \frac{\sigma_x+\sigma_y}{2} + \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2} \quad (4)$$

$$\sigma_{min} = \frac{\sigma_x+\sigma_y}{2} - \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2} \quad (5)$$

The maximum and minimum stress can be reached as below.

$$\sigma_{max} = \frac{\sigma}{2} + \sqrt{\frac{\sigma^2}{4} + \tau^2} \quad (6)$$

$$\sigma_{min} = \frac{\sigma}{2} - \sqrt{\frac{\sigma^2}{4} + \tau^2} \quad (7)$$

The principal stress can be decided from above calculation. They are shown as formula 8.

$$\sigma_1 = \sigma_{max},\ \sigma_2 = 0,\ \sigma_3 = \sigma_{min} \quad (8)$$

According to the 3rd strength theory of $\sigma_1 - \sigma_3 \leq [\sigma]$, the diameter of hook can be decided. Using formula (1) ~ (8) with the 3rd strength theory, the diameter of hook is shown as formula 9.

$$d \geq \sqrt[4]{\frac{16F_V^2+64F_H^2}{\pi[\sigma]^2}} \quad (9)$$

Remark: d-The diameter of hook, [σ] -allowable stress.

According to the quality of shield steel plates, we get the diameter calculation table for the hooks of the fixing parts. It is shown as table 2.

Strength Calculation for Plug Welding

According to the previous analysis, plug welding is used to join the two parts. The draft of plug welding is shown as figure 3. The diameter of plug welding is set as d, and the thickness is set as h.

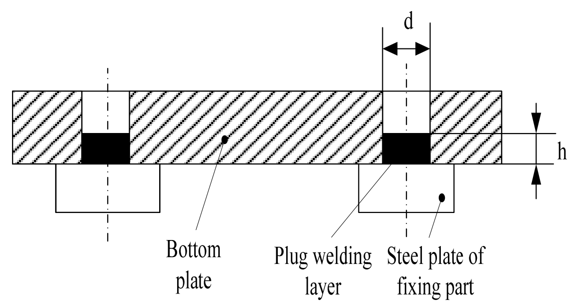

Figure 3: Draft of plug welding.

The area of plug welding is used to undergo the horizontal load. The force mode is shearing. The shearing stress can be got by formula 10.

$$\tau_H = \frac{4F_H}{\pi d^2} \leq [\tau] \quad (10)$$

So the diameter should meet formula 11.

$$d \geq \sqrt{4F_H/(\pi[\tau])} \quad (11)$$

In the thickness direction, the squeezing and shearing deformation is considered at the same time. The shearing stress can be decided by formula 12 and 13.

$$\tau_V = \frac{F_V}{\pi dh} \leq [\tau] \quad (12)$$

$$\tau_{jy} = \frac{F_H}{dh} \leq [\tau] \quad (13)$$

The thickness of plug welding can be decided from formula 12 and 13, which is shown as below formula 14.

$$h \geq F_H/(d[\tau]) \quad (14)$$

The diameter and thickness is listed as below table 3.

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Table 3: Diameter and Thickness of Plug Welding

Beam Dump	Quality (t)	α	F_H,F_V (N)	[τ] (MPa)	Number	Min d (mm)	Min H (mm)	Set d (mm)	Set H (mm)
L-DUMP-B	102	0.2	199,920	110	4	24.06	9.09	50	20
I-DUMP	74	0.2	145,040	110	4	20.49	6.59	50	20
R-DUMP	402	0.2	787,920	110	8	33.77	17.91	50	20

CONCLUSIONS

It is an important context to design the fixing part to resist the earthquake for the installation of shield steel plates. The structure form of the fixing part was reached by the study of the properties of building operations. The force mode and load of earthquake was decided by the analysis of the force action of earthquake. Then the strength theory was used to get the dimension of the fixing part and plug welding. The design of resistance to earthquake was solved in the end.

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