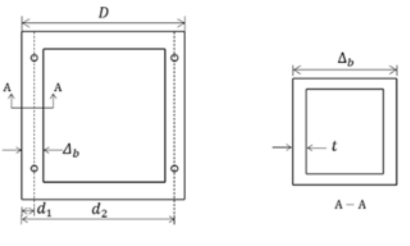
Rocking Stiffness of Electric Cabinet Considering the Local Deformation at the Base

Minsoo Han [a], Sung-Gook Cho [b*], Kee-Jeung Hong [c], Abhinav Gupta [d]
[a] *Researcher, R&D Center, Innose Tech Co. Ltd., Korea*
[b] *Director, R&D Center, Innose Tech Co. Ltd., Korea*
[c] *Professor, Civil and Environmental Engineering Dept., Kookmin University, Korea*
[d] *Professor, Civil, Construction and Environmental Engineering Dept., NC State University, USA*
[*] *Corresponding author: sgcho@innose.co.kr*

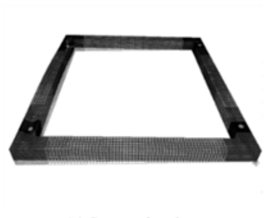
1. Introduction

The floor response spectrum resulting from the amplification of the floor behavior within the cabinet is called the in-cabinet response spectrum (ICRS). In order to assess the seismic safety of a relay, its functioning should be checked by testing using the in-cabinet response spectrum at the location where the relay is installed [1, 2]. It is not easy to create finite element models to compute dynamic characteristics or in-cabinet response spectrum for the large number of cabinets installed in nuclear power plants. EPRI has proposed a method to briefly calculate the in-cabinet response spectrum in the practice, but this method can give excessively conservative or unconservative results.

This paper introduces an ICRS generation method based on the Ritz vector method proposed by Gupta et al. [3]. Several studies have shown that the rocking mode of the cabinet has a significant effect on the cabinet response [4, 5]. This study develops the mathematical model for the rocking mode of a steel-box cabinet, which is widely used in Korean nuclear industry, based on the results of performing seismic response analysis.



(a) Plan view of the base frame (b) Section view



(c) Isometric view

Fig. 1. Cabinet mounting arrangement in different views

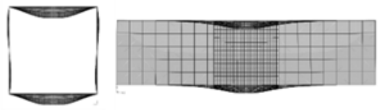
2. Rocking Stiffness of Cabinet

2.1 Mounting arrangement

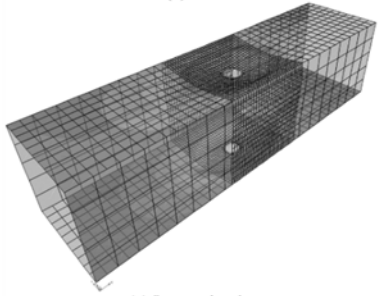
Rocking stiffness of a steel-box cabinet can be represented by an equivalent spring coefficient. The base of this cabinet is the steel frame with the tubular section, and the mounting arrangement of the anchors is shown in Fig. 1.

2.2 Formulation

Most rocking behavior of cabinet is produced by localized deformation of the plate around the anchor and bending deflection of the base frame. Fig. 2 shows the cup-like localized deformation that occurs around the anchor on the tubular section frame.



(a) Front elevation view (b) Side elevation view



(c) Isometric view

Fig. 2. Cup-like localized deformation of the base plate around an anchor bolt

The vertical stiffness formulation by localized deformation can be defined using the total potential energy of the plate, U, as shown in Eqn. (1).

$$U = \frac{Et^3}{24(1-\nu^2)} \int_0^{a_x\Delta_b} \int_0^{a_z\Delta_b} \left(\frac{\partial^2 u}{\partial x^2}\right)^2 + 2\nu \frac{\partial^2 u}{\partial x^2}\frac{\partial^2 u}{\partial z^2} + 2(1-\nu)\left(\frac{\partial^2 u}{\partial x \partial y}\right)^2 + \left(\frac{\partial^2 u}{\partial z^2}\right)^2 dxdz \tag{1}$$

where u is the transverse plate deflection; E is the Young's modulus of elasticity for base plate material; ν is the Poisson's ratio for base plate material; and t is the base plate thickness, respectively. Δ_b is width of tubular-section base-frame and a_x , a_z are constant for representing a region of cup-like deformation. Differential U with respect to the transverse plate deflection u gives us the corresponding vertical force which generate the total potential energy U. Then, differential of the vertical force with respect to the transverse plate deflection u yields the corresponding equivalent vertical spring coefficient such as

$$K_v = C\frac{Et^3}{12(1-\nu^2)}\frac{1}{\Delta_b^2} \qquad (2)$$

where C is a constant whose value is governed by the choice of a shape function for plate deflection.

Let's assume that spaces between the anchors are large enough so that there is no interference between the plate localized deformations at neighboring anchors. This vertical behavior can be represented by an equivalent vertical spring. In addition, the bending behavior of the tubular beam has effect on the rocking stiffness of the cabinet as shown in Fig. 3.

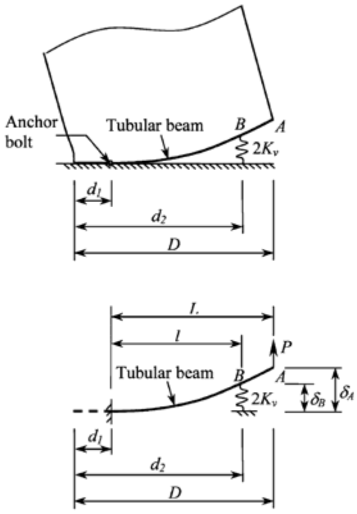


Fig. 3. Simplified model for rocking stiffness composed with the vertical spring due to cup-like local deformation and bending stiffness of tubular beams [4]

2.3 Parametric study

To obtain the rocking stiffness based on thickness t and width of tubular-section base-frame Δ_b, several static analyses were performed. The constant value C was calculated from the analyses results. The rocking stiffness and the constant value C are shown in Fig. 4 and Fig. 5, respectively.

3. Conclusions

Whereas the rocking stiffness of the electrical cabinet has a strong influence on the dynamic characteristics, a method to consider this has been proposed through analytical derivation and numerical examples. The rocking stiffness has been derived considering localized plate deformation and bending deflection in the base frame with different width and thickness.

In Fig. 5, the values of constant C are varying over the width and thickness of the base frame, so that it is necessary to present more general values of the constant through further study in order to use it in practice.

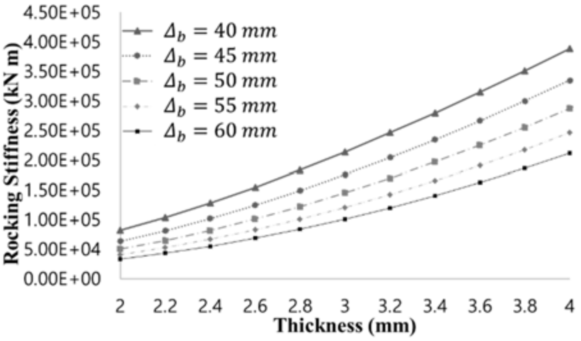


Fig. 4. Rocking stiffness of the electrical cabinet with tubular-section base-frame

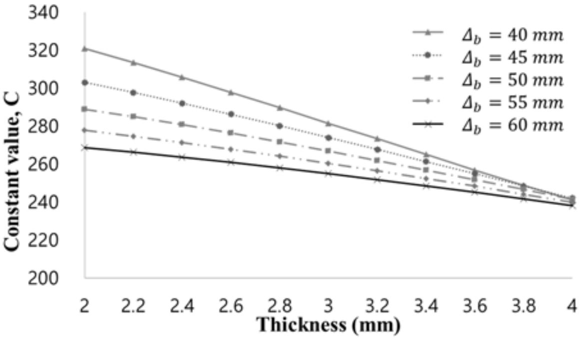


Fig. 5. Constant value C of the electrical cabinet with tubular-section base-frame

ACKNOWLEDGEMENT

This work was supported by the Development of Seismic Fragility Analysis Program for Class 1E Equipment Electric Cabinet in Nuclear Power Plants of the Korea Institute of Energy Technology Evaluation and Planning(KETEP) grant financial resource from the Ministry of Trad, Industry & Energy, Republic of Korea (No. 20161520101270).

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