Design of Base Slabs For Three Components Of Earthquake

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Base slabs for complex buildings such as nuclear power plants must be designed for the moments (M_x, M_y, M_{xy}) that develop from static and dynamic forces. The design moments are given by[1]

$$M_x^* = M_x + M_{xy} \tan\theta, \quad M_y^* = M_y + M_{xy} \cot\theta \tag{1}$$

where θ is the direction of the failure section. For positive capacities one satisfied the conditions, $M_y^* \geq M_x$ and $M_y^* \geq M_y$; and for negative capacities, $M_x^* \leq M_x$, $M_y^* \leq M_y$. The direction θ can be so chosen such that the total required capacities are minimum. The above equations can also be derived based upon the Principle of Minimum Resistance[2].

In earthquake design, only SRSS (Square Root of the Sum of Squares) values of the relevant parameters are conventionally considered. For calculating the design moments using Equation (1), the combination

$$M_x = M_x^\circ \pm \bar{M}_x, \quad M_y = M_y^\circ \pm \bar{M}_y, \quad M_{xy} = M_{xy}^\circ + \text{sign}\,(M_{xy}^\circ)\,\bar{M}_{xy} \tag{2}$$

is used in which the superscript ($^\circ$) denotes the static forces and the bar ($\bar{}$) denotes the SRSS values due to the earthquake forces. Equations (1) and (2) will yield conservative results because the worst effects will never occur simultaneously. A more rational alternative method is presented in Reference 3 in which $\bar{M}_x$, $\bar{M}_y$ and $\bar{M}_{xy}$ of Equation (2) are in effect defined as

$$\bar{M}_x = \alpha_{in} M_{xin}, \quad \bar{M}_y = \alpha_{in} M_{yin}, \quad \bar{M}_{xy} = \alpha_{in} M_{xyin} \tag{3}$$

in which $\alpha_{in} = M_{\theta in}/(M_{\theta in} M_{\theta in})^{1/2}$, where M_θ is the moment in θ direction, i the direction of earthquake excitation (i = 1, 2, 3) and n the mode of vibration; the repeated subscripts imply summation. The two design methods may be compared using a simple two direction (i = 1, 2) excitation one mode (n=1) response examples shown in the table below.

	Seismic Direction		Static	Design Moments			
				Conventional		Reference 3	
	i=1	i=2		Positive	Negative	Positive	Negative
M_x	10	8	10	42.2	22.2	31.0	21.26
M_y	-15	8	10	46.4	26.4	32.4	12.0
M_{xy}	5	8	-10				

As shown, the conventional method yields total design moments about 42% higher than those proposed in Reference 3. While the comparison will vary with design problems, the proposed method will always give a safe and more economical design.

References

1. Wood, R. H., "The Reinforcement of Slabs in Accordance with a Predetermined Field of Moments," Concrete, February, 1968.
2. Cardenas, A. and Sozen, M. A., Strength and Behavior of Isotropically and Nonisotropically Reinforced Concrete Slabs Subjected to Combination of Flexural and Torsional Moments, SRS No. 336, University of Illinois, 1968.
3. Gupta, A. K. and Chu, S. L., "Design of Reinforced Concrete Structures Subjected to Three Components of Earthquake," Nuclear Engineering and Design, pp. 96-101, 1976.

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