# CS 6 -16〔 I 〕 SEISMIC MACRO-ZONATION OF THE PHILIPPINES BASED ON THE EXPECTED PEAK GROUND ACCELERATION

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**SUMMARY:** The seismic hazard in terms of the expected peak ground acceleration (PGA) in the Philippines is calculated from historical earthquake occurrence data using a new computer program called the Seismic Hazard Mapping Program (H-MaP). Central Luzon, which was heavily damaged during the 16 July 1990 earthquake, is found to have a high seismic hazard. Based on the calculated seismic hazard and the design seismic coefficients, a new seismic zonation map of the Philippines is proposed.

**SEISMIC HAZARD:** A new computer program called the Seismic Hazard Mapping Program was used to calculate the seismic hazard in the Philippines. To evaluate the seismic hazard parameter for one site, all earthquakes with epicenter within 300 kilometers from the site are selected from the USGS database (1963-1990). The PGA at the site is estimated by using the attenuation law of McGuire, 1977 (Eq. 1), where $a$ is the estimated PGA in g, $M$ is the magnitude, and $r$ is the hypocentral distance in kilometers. With the estimates of the PGAs for all earthquakes, regression is done to relate the PGA with the occurrence rate (Eq. 2), where $y$ is the peak ground motion, $\nu$ is the mean annual occurrence rate, and $a$ and $b$ are regression constants. By assuming a Poisson process, the seismic hazard can be calculated.

$$a = 0.482\, e^{0.64\, M}\, (r + 25)^{-1.3} \quad ; \qquad \log \nu = a + b \log y \qquad (1), (2)$$

Fig. 1 shows the distribution of the 100-year peak ground acceleration. A comparison of the hazard map with a plot of the earthquake epicenters showed that regions with high seismic risk correspond to those which experienced several shallow earthquakes. These regions include Central Luzon which suffered heavy damage during the 16 July 1990 earthquake.

**DESIGN CODE:** The seismic design provisions of the Philippines are basically an adaptation of the Uniform Building Code in the United States. To design for the lateral seismic load, the modified seismic coefficient method is used. If the seismic coefficients of the Philippines and of Japan are compared (Fig. 2), it can be seen that the design levels of the Philippines are considerably lower than those of Japan. This is especially true for structures with fundamental periods from 0.2s to about 1.2s, where the difference is from about 0.5 to 0.6.

For short period structures, the response of the structure is close to the PGA. For this case, the return period for exceeding the seismic coefficient is given in Fig. 3. It can be seen that there are several regions which have high probabilities (low return periods) to exceed the design seismic coefficient.

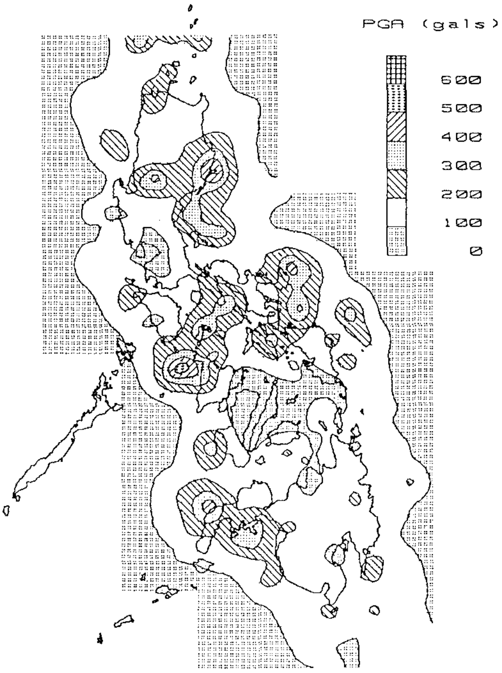

Fig. 1 100-year peak ground acceleration

From the above discussions, a new seismic zonation map based on the expected PGA is proposed (Fig. 4). While the National Structural Code of the Philippines (NSCP) specifies that the zone factor, Z, to be used for design is 1.0, the proposed zonation divides the country based on the relative seismic hazard. Table 1 shows the mean and standard deviation of the 100-year PGA for zones 2 to 4 while Table 2 shows the mean and standard deviation of the return period for exceeding the current design seismic coefficients. Zone 1 is historically aseismic and the seismic hazard in this region was not calculated. Zone 4 corresponds to a return period of about 40 years or less; Zone 3, approximately from 40 to 200 years; and Zone 2, more than 200 years. By taking Zone 3 as the reference, the zone factors can be computed by normalizing the mean of the expected PGA with respect to Zone 3. It should be noted, however, that the values in Tables 1 and 2 were computed from the entire analysis area which also includes the sea. Currently, a scheme for calculating the zone factors for the land portion only is being studied. It should also be noted that the zonation map is applicable to short period structures.

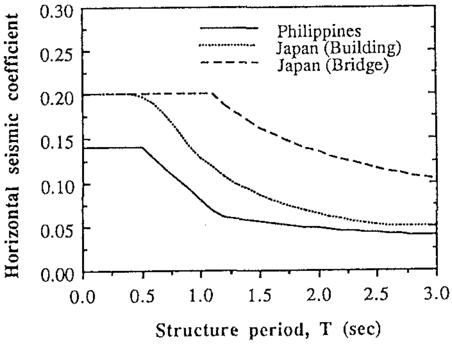

Fig. 2 Design horizontal seismic coefficients for the Philippine building code and the Japanese building and bridge codes

Table 1. 100-year PGA for the seismic zones

| ZONE | Mean ($cm/s^2$) | Std. dev. ($cm/s^2$) | Zone Factor, Z |
|---|---|---|---|
| 1 | - | - | 0.5 |
| 2 | 66.7 | 19.8 | 0.7 |
| 3 | 142.2 | 26.8 | 1.0 |
| 4 | 269.9 | 61.4 | 1.5 |

Table 2. Return period for exceeding the design seismic coefficients

| ZONE | Mean (yrs) | Std. dev. (yrs) |
|---|---|---|
| 2 | 2446.1 | 4379.5 |
| 3 | 97.9 | 43.6 |
| 4 | 26.4 | 7.9 |

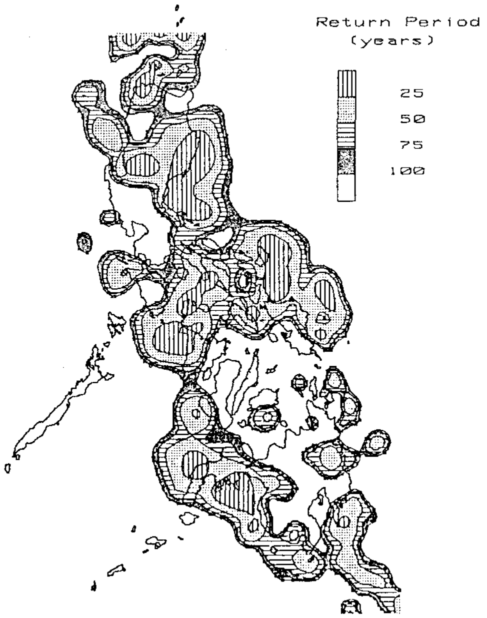

Fig. 3 Return period for exceeding design seismic coefficient

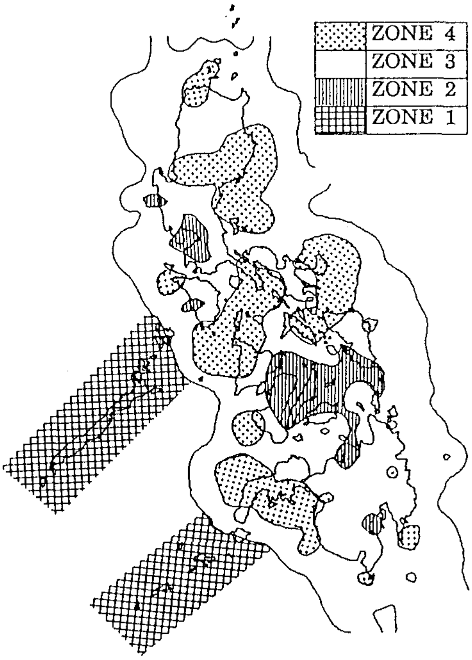

Fig. 4 Proposed seismic zonation

**CONCLUDING REMARKS:** By identifying the regional distribution of the seismic hazard in the Philippines, engineers and planners can make more sound decisions on seismic considerations. More rational seismic design levels for the country may be obtained by adjusting the seismic coefficients based on the relative seismic hazard.

**REFERENCES:**

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