STRUCTURAL RESPONSE OF HILLSIDE FOUR STOREY REINFORCED CONCRETE EXISTING BUILDING UNDER SEISMIC EXITATION

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Abstract: Most of Indonesia's territory is located in the tectonic earthquake zone which is very active with relatively high peak ground acceleration. Based on the records of the USGS, Indonesia has had more than 150 earthquakes with magnitude more than 7 during the last decade. Earthquake zoning maps and Earthquake Resistant Building Codes have been in effect since 1982, and are renewed every 5 years, which tend to be more stringent requirements. The problem that always arises is to carry out structural assessments of existing buildings that are very large in number and have been built at that time based on the old design code. The problem becomes more complicated when the existing structures assessed are in a critical category, because they are located on the hillside with steep slopes. This paper discusses the assessment of the existing structure of a four-story building made of reinforced concrete, which is located on a slope of around 30^0. So many similar structures are found in various hills and mountain slopes in the country. Assessment is carried out by first conducting sample tests and non-distructive tests to assess the quality of existing concrete (after more than 8 years of service) in various structural elements, reconstructing steel reinforcement data, and re-measuring the dimensions of structural elements, along with the foundation system.

Structural analysis is carried out based on assessed material properties data. Most of the building's base is beared on the excavated ground and the rest is on the fill. The foundation system is in the form of bored piles which are not uniform in length (because they have to adjust to the existing steep slope). The further downhill the longer the foundation, so that the elevation of the virtual fixing point of the pile foundation will also be deeper. The structural analysis carried out in this assessment used Finite Element Method, and includes: (a) eigenvalue analysis to obtain natural frequencies and modes of the 1^{st}, 2^{nd}, and 3^{rd}; (b) time history analysis to obtain structural responses due to earthquakes; (c) checking the capacity of structural elements (beams, columns, floor slabs, structural walls and pile foundations), and (d) retrofitting designs on structural elements that do not meet the strength and ductility requirements. However, due to the limited space, only the results of dynamic properties analysis and time history analysis are discussed in this paper.

The analysis results indicate that: (a) the 1^{st}, 2^{nd} and 3^{rd} natural frequencies of the structure, respectively, are 0.885 Hz, 0.918 Hz, and 1.021 Hz; (b) the 1^{st} mode shape is torsional, the 2^{nd} is translation, and the 3^{rd} is torsional; (c) because the fundamental shape mode is torsional, the distribution of shear forces on the bored piles foundation is uneven, and the short piles receive shear forces that are relatively much larger than the longer piles; (d) with existing reinforcement, the short piles are unable to withstand shear forces (in combination with axial force and bending moment), due to the earthquake such that the building is declared unsafe and in needs of retrofitting on the pile foundation system.

Keywords: Seismic Response, Hillside Building, Structural Assessment, Steep Slope