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Soil Dynamics and Earthquake Engineering
Volume 179, April 2024, 108460

Discussion on "Fragility curves for assessment of seismic vulnerability of buildings on slopes" by Magapu and Setia, Soil Dynamics and Earthquake Engineering 173 (2023) 108069

Vaibhav Sharma [a], Dhiraj Raj [a], M. Bharathi [b]

[a] Department of Civil Engineering, MNIT Jaipur, Jaipur, 302017, Rajasthan, India
[b] Department of Civil Engineering, SKIT Jaipur, Jaipur, 302017, Rajasthan, India

Received 17 October 2023, Accepted 22 November 2023, Available online 23 January 2024, Version of Record 13 March 2024.

https://doi.org/10.1016/j.soildyn.2024.108460
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The authors [1] have developed the seismic fragility curves for the buildings, with step-back and step-back setback configuration, constructed in hilly areas, including the influence of short column effect and live load eccentricity. They have performed Incremental Dynamic Analysis (IDA) to obtain the dynamic capacity curves using a set of eleven near-field ground motions. Authors have developed the fragility curves for five limit states, namely Operational Performance (OP), Immediate Occupancy (IO), Damage Control (DC), Life Safety (LS), and Collapse Prevention (CP) as per FEMA 273 [2]. By comparing the fragility curves, they found that the building with step-back setback configuration with short column effect and live load eccentricity in the plan yields the highest probability of damage for all limit states. We appreciate the efforts made by the authors to conduct this study.

However, a critical review of the original manuscript reveals that the authors [1] failed to comprehend the findings and results of the studies referred. The authors have put in minimal effort to perform the literature review and overlook various relevant studies [[3], [4], [5]]. The authors also did not adhere to the guidelines and recommendations in the standards/codes for developing fragility curves.

Hence, we would like to highlight this article's crucial aspects and draw the attention of readers through this detailed discussion.

1. Introduction

The authors [1] have stated that, as per IS: 1893(Part I)-2016 [6], the effective peak ground acceleration (EPGA) in the Sikkim region is 0.24g for the Maximum Considered Earthquake (MCE). It is quite confusing for the reader, as IS: 1893(Part I)-2016 code provides no information regarding the EPGA and MCE. The authors [1] have mentioned that an earthquake with 6.9 magnitude and 0.18g PGA was measured in Gangtok as per IS: 1893. However, no such information is found in any version of IS: 1893. It is difficult for the reader to understand the incomplete sentence in the original manuscript, which states, "A numerical study on the seismic behavior of reinforced concrete frame buildings situated on hill slopes." Further, from the statement, "A detailed survey to develop a building stock inventory in Uttarakhand, India concluded that 60% of the buildings were low-rise and mid-rise reinforced concrete structures where code provisions were violated. The slope angle of these buildings ranged between 15° and 30°, and the maximum number of floors was four", it is not clear that who has conducted this study, proper citation is required.

2. Incremental Dynamic Analysis

The authors [1] have stated that the IDA method was introduced by Bertero in 1977, but the citation is missing. Further, the scaling of the ground motions is a critical issue for performing IDA and developing the fragility curves. The authors have not provided the PGA values corresponding to each ground motion in Table 1. In addition, the minimum and maximum scaling factors (as large scaling factors might have bias effect on the results [7]) corresponding to each ground motion are also not provided anywhere in the original manuscript.

3. Ground motion selection

The authors [1] have cited and stated that “Vamvatsikos and Cornell (2002) (citation number 11 in the original manuscript) suggested that 10–20 ground motion records are adequate for low-rise buildings.” However, no such statement was found in the referred publication. Moreover, the authors have further stated that they have selected 11 numbers of near-field ground motions (distance of source less than 20 km) and their details are summarized in Table 1 of the original manuscript. However, contrary to the statement of the authors [1], FEMA P695 [8] defines the “Near-Field” record as a set of ground motions recorded at sites less than 10 km from fault rupture. Now, it is difficult for the reader to comprehend the statement regarding “Near-Field”. In addition, the authors [1] have cited the source of the FEMA P695 [8] document incorrectly (see citation number 13 of the original manuscript).

Further, the authors have individually scaled or matched the eleven selected ground motions with the design spectrum in the range of $0.2T_1$ to $1.5T_1$, here, T_1 is the fundamental period of each building to minimize the difference between the design response spectrum and the response of the ground motions. It is evident that when the ground motion is matched with the target spectrum in a particular range, the PGA of the original ground motion will alter. Now, it is difficult for the reader to comprehend which PGA value was scaled for performing the IDA.

4. Engineering Demand Parameters

The authors referred Vamvatsikos and Cornell [9] [see citation no. 11 of original manuscript] and claimed that for moderate period building and near-fault ground motion, PGA is a more effective Intensity Measure (IM) than 5% damped first mode spectral acceleration ($S_a(T_1,5\%)$) and produces more consistent results. However, Vamvatsikos and Cornell [9] pointed out that a first mode dominated structure is sensitive to the strength of the frequency content near its first-mode frequency, which is well characterized by the first mode spectral acceleration ($S_a(T_1,5\%)$), rather than PGA. Hence, it is a contradictory statement against cited literature and more confusing for readers.

5. Numerical Study

The authors [1] have considered five different types of buildings (M_0, M_1, M_2, M_3, and M_4) in this study. Among these buildings, M_1 and M_2 refer to a step-back setback configuration with a difference in mass eccentricity in plan. Similarly, buildings M_3 and M_4 correspond to a step-back setback frame with short column defects and are distinguished by mass eccentricity in plan. Further, the authors stated that eccentricity has been introduced in the structure by distributing the live load in the plan. Surprisingly, despite several mentions of the plan of the building, no such plan exists in Fig. 2 or even anywhere in the entire original manuscript. This omission leaves the readers in a dilemma to distinguish between models M_1 and M_2 and models M_3 and M_4 and depicts the ignorance of the authors.

The authors [1] have further stated that the buildings were designed as per IS-456:2000 [10], and the details of building components are given in Table 2. As per Table 2, the longitudinal reinforcement in the topside of the beam is 5bars of 16 mm diameter, whereas for the bottom side, 4bars of 16 mm diameter is used. This seems a very strange design to the reader, and it is difficult to understand the situation where the beams are in tension at the top and in compression at the bottom for the considered models under gravity or seismic load.

6. Fragility Curves

The authors [1] have carried out IDA by performing 110 non-linear time history analyses to generate the dynamic capacity curves and derive the fragility functions, which take the form of lognormal cumulative distribution functions with a mean value and logarithmic standard deviation, as described in section 7 of the original manuscript.

In order to derive probabilistic fragility curves from IDA, a two-parameter (median and log-standard deviation) based lognormal distribution function, obtained from the simulated damage data, is used by various researchers for statistically correlated and predefined damage limit states [[11], [12], [13], [14], [15], [16], [17]].

The authors [1] have used the mean value of the probability distribution and standard deviation, as given in Table 5 of the original manuscript. However, they did not use the median value and the total variability, including the uncertainty in the definition of damage states and the uncertainty in the estimation of response and resistance (capacity) of the structure due to variability in structure properties (design, construction material, and construction practices), to derive the fragility curves. These significant errors lead to highly inaccurate fragility functions and confirm that the outcomes of the entire study, as it relies on unreasonable values of different parameters, are absurd (can be seen as given in Table 5 of the original manuscript). Hence, it will naturally yield erroneous results with no practical utility.

7. Results and Discussions

The authors have presented the results in terms of the probability of damage for various limit states of considered buildings (Operational (OP) at 0.5g, Immediate Occupancy (IO) at 0.7g, Damage Control (DC) at 0.8g, and Life Safety (LS) at 1.0g). It is not clear why the authors have chosen 0.5g, 0.7g, 0.8g, and 1.0g corresponding to different limit states to present the results despite the building being designed for seismic zone V. Further, in conclusions, points 5 and 6 seem irrelevant as they deal with retrofitting techniques and bracing systems which are not addressed in the present study.

We hope the authors will find the observations of the discussion useful.

Data availability

No data was used for the research described in the article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Recommended articles

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