Evaluation of Ground Motion Definition on the Seismic Analysis of Reinforced Concrete Moment Frame Structure

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Abstract. The primary objective of the study is to analyze the effect of the horizontal definition in the ground motion selection, in which, how the target spectra of DBE and MCE resulted from the geometric mean method and NGA West-2 $Sa_{RotD100}$, the maximum direction method is different from each other. The analysis of the seismic performance of the building is the secondary aim of the research. The linear design methods of equivalent lateral force analysis, response spectrum and seismic response history analysis are performed based on the Myanmar seismic design code to figure out and compare the building responses such as story displacement, story drift, story base shear, and story overturning moment. In this study, the irregular shaped RC building structural responses are also explored with equivalent lateral force analysis (EQLF), response spectrum analysis (RSA) and linear response history analysis (LRHA). The recent ground motion definition response shows great potential in improving the performance-based design of considered structures.

1. Introduction
The static and dynamic structural analysis become primary concern in earthquake engineering to predict the structural behavior subjected to earthquake ground motions. The ground motion selection becomes one of the important issues in the seismic analysis to perform dynamic analysis. An earthquake is a natural disaster and can happen naturally without warning. Moreover, the structure tends to collapse and it may harm the life of people during earthquake excitations. Thus, the proper design for the structure is needed. The seismic provision codes are proposed to ensure the structure and occupant benefits in each country respectively. Since Myanmar is one of the earthquake-prone zones in Southeast Asia, the seismic performance analysis is recommended in this region. Myanmar National Building Code, 2016 [1] which is adapted from ASCE 7-05 [2] is stipulated to examine the analysis by the Federation of Myanmar Engineering Society (Fed. MES). As for the ground motion definition, the geometric mean spectrum is the most widely used horizontal definition to combine the two orthogonal spectral accelerations into a single numerical value [3]. The definition is also used in MNBC, 2016 and the framework is also similar to the National Earthquake Hazards Reduction Program (NEHRP), 2003 Seismic Design Provision [4]. Nowadays, the updated version of seismic provision and ASCE 7-16 [5] provide the maximum direction ground motion instead of geometric mean of two orthogonal ground motions components due to its short coming definition. The geomean definition does not give the ground motion values which vary with the orientation of recording axes. Thus, researchers developed the definition of median spectral acceleration ($Sa_{RotD50}$) and maximum spectral acceleration ($Sa_{RotD100}$) overall orientation [6]. In this study, the factors developed by Shahi and Baker, 2013 [7] which are the ratio of maximum spectral acceleration ($Sa_{RotD100}$) to median...
spectral acceleration ($S_{a_{rotD50}}$) at discrete period is used to predict the maximum spectral acceleration overall orientations. In time history analysis, the different responses of a structure could be resulted by the different ground motions. There are three orthogonal components of ground motion that accelerogram records: two in the horizontal direction and one in vertical direction. In this study, the two-dimensional intensity of ground motion is taken into account to compute response spectrum by using two orthogonal horizontal components of the ground motion. The research objective of the study is to figure out how these two-horizontal definitions; regional code ground motion definition and the maximum ground motion effects on the reinforce concrete moment frame structure. The study location is in Mandalay, Myanmar which is very close to the major strike slip fault and equivalent lateral force analysis (EQLF), response spectrum analysis (RSA) and linear response history analysis (LRHA) are performed according to the MNBC, 2016. This research work is an attempt to reach on more accurate conclusion to reduce their effect on the structure.

2. Literature Review

A literature review states that related to the characteristic of ground motions, and seismicity of Mandalay City, Myanmar. A brief introduction about the ground motion characteristics, horizontal definitions of ground motion and overview of seismic hazard level for the study location are discussed in this section.

2.1 Characteristics of Ground Motions

In earthquake engineering, ground motion referred to as the ground acceleration, velocity and displacement. There are three parameters in terms of amplitude: peak ground acceleration (PGA), peak ground velocity (PGV) and peak ground displacement (PGD). They are the particular interests in most cases amplified when transmitted through the structure by ground vibration. The strong motion instruments are used to measure the earthquake ground motion and record the ground acceleration [8]. The recorded acceleration consists of two horizontal components and one in vertical direction. There are many ways to describe the earthquake ground motion intensity measures. 5% damped spectral acceleration can also be described in either single arbitrary components or the combination of two orthogonal horizontal components. The geometric mean response spectrum which is the combination of two horizontal orthogonal ground motion components is the most widely used horizontal definition and has been used in ASCE 7-05 and attenuation relationship. But the spectral acceleration of geomean depends on the sensor recording orientation. Thus, researchers proposed many others orientation independent definitions: $S_{a_{GMrodDun}}$ and $S_{a_{GMrodInn}}$ by Boore et al, 2006 [9] and $S_{a_{rodDun}}$ and $S_{a_{rodInn}}$ by Boore, 2010 [6] to remove the orientation independence. The PEER Ground Motion Database introduced new spectral acceleration to remove the recorded orientation; $S_{a_{rotD50}}$ (median spectral acceleration) and $S_{a_{rotD100}}$ (maximum spectral acceleration) as an intensity measure. Current ground motion prediction equations (GMPE) use median spectral acceleration ($S_{a_{rotD50}}$) which is the 84th percentile of the geometric mean response [10]. Shahi and Baker developed the model for maximum direction spectral acceleration ($S_{a_{rotD100}}$) by using over 3000 ground motions from the NGA West-2 Database. The multiplicative factor which is the ratio of $S_{a_{rotD100}}$ to $S_{a_{rotD50}}$ is evaluated to predict the maximum spectral acceleration of a model at a site. Shahi and Baker (2013) proposed that the ground motion directionality referred to as the polarization of the ground motion [10]. This leads to the discrepancy between response spectra definitions. The unpolarized case, e.g., “1994 Chi Chi earthquake” is defined when the ground motion has an approximately equal response spectrum over all orientations at a given period and the value of $S_{a_{rotD100}}$ to $S_{a_{rotD50}}$ ratio is nearly 1. Nevertheless, the value of the ratios is equal to 1.414 if the ground motion is in strongly polarized case by the “1984 Morgan Hill earthquake”. Thus, the value of $S_{a}$ for any ground motion will be within the range of 1 to 1.414. [7]. According to Huang et al, 2007, the spectral demand by geomean ground motion can be much smaller than the maximum demand in the near fault region. The research is emphasized on the seismic records which are selected with seismic parameters of 6.5 moment magnitude or larger and less than 15 km site to source distance. The resulted earthquakes ground motion by next attenuation
relationships gives maximum direction response spectral acceleration of the 110% of 5% damped at short period and 130% at 1 second period. [11].

2.2 Seismicity of Myanmar
Myanmar is one of the earthquake-prone zones in Southeast Asia. In this study, Mandalay City, Myanmar is selected for the site consideration. It is the second largest city and covers approximately from latitude 21° 51’ to 22° 1’ N and Longitude 96° 3’ to 96° 8’ E. It is located very close to the most active dextral Sagaing fault in Myanmar which is a major north-trending right lateral strike-slip fault and 8 km away from Mandalay City [12]. Mandalay City has a population around 1.3 million, according to the 2014 records and grow gradually. Thus, the scale of disaster from seismic excitation will be increased in the cities due to urbanization the vulnerability is increased. MNBC, 2016 brings together the information on the ground motion parameters which are described by the maximum considered earthquake (MCE) spectral response acceleration with 5% damping ratio at short period, $S_s(0.2 \text{ sec})$ and at one second period, $S_t(1.0 \text{ sec})$ of Mandalay City are 2.01g and 0.8g respectively [1]. According to the study of the seismic microzonation report of Mandalay City, the spatial variation of $V_{S30}$ ranges from 220 m/s to 340 m/s for nearly all of the sites in Mandalay [13]. Thus, the site class D (stiff soil) is defined for this $V_{S30}$ range [14]. The response spectrum at design and maximum considered earthquake levels for both geomean and maximum spectral accelerations are illustrated in figure 1. The geomean code spectra for DBE and MCE are constructed by applying spectral acceleration parameters provided by MNBC, 2016 while the DBE and MCE of $S_{a\text{RotD100}}$ spectra are constructed by using factors of Shahi and Baker, 2013 [7].

![Figure 1](image_url)

**Figure 1** MCE and DBE of geomean and $S_{a\text{RotD100}}$ target spectra for Mandalay City.

3. Research Methodology
The study is carried out to analyze the behaviour of soft story rectangular building, provided as 4m base height and 3m typical floor height. The model of the building is created in ETABS software [15] and building structural properties are defined as table 1 according to the Myanmar National Building Code, 2016. Figure 2 shows the plan, elevation and 3D views of the building. Moreover, the effective stiffness of the structural elements such as beams, columns and slabs are taken into account according to the American Concrete Institute Code, 2005 [16]. Since Mandalay City, Myanmar is selected as the study site location, the seismic category is considered as E and soil type is stiff soil according to the Thein et. al, 2018. The applied loads such as super dead loads, live loads and earthquake loads to the office building structures are according to the MNBC, 2016 part III and Part IV respectively in table 2.
The seismic parameters used in this study are shown in the table 3 for the inelastic behaviour of the structure. The analysis is carried out by equivalent lateral force analysis, response spectrum analysis and linear response history analysis and determined the story displacement, story drift, story overturning moment and story shear. In this study, the designed base earthquake spectra and maximum considered earthquake spectra for both geomean and $S_a_{RotD100}$ is illustrated according to the regional code and by using the multiplicative factors developed by Shahi and Baker, 2013 [7]. The recorded earthquake data are obtained from NGA West-2 PEER Ground Motion Database [17] to perform linear response history analysis. After the analyses are done, the results obtained from ETABS software are turn observed to form conclusions.

**Figure 2.** Plan, elevation and 3D views of model.

**Table 1.** Description of the building

| Building Type                  | (Office)                  |
|--------------------------------|----------------------------|
| No. of Story                   | 10                        |
| Bay size                       | 4.5m                      |
| Height                         | 4m (Base)                 |
|                                | 3m (Typical)              |
| Beam Dimension                 | 350mm*500mm               |
| Column Dimension               | 600mm*600mm               |
| Slab Depth                     | 130mm                     |
| $f_c'$                         | 28 MPa                    |
| $f_y$                          | 413 MPa                   |

**Table 2.** Load assignment (MNBC, 2016)

|                     |                  |
|---------------------|------------------|
| Super Dead Load     | 1.5kN/m$^2$ (Typical) |
|                     | 1kN/m$^2$ (Roof)  |
| Live Load           | 2.4kN/m$^2$ (Typical) |
|                     | 1kN/m$^2$ (Roof)  |
Table 3. Seismic parameters used in this study (MNBC, 2016)

| Parameter | Value |
|-----------|-------|
| $S_s$     | 2.01  |
| $S_l$     | 0.8   |
| $S_{DS}$  | 1.34  |
| $T_L$     | 6     |
| $R$       | 8     |
| $\Omega$ | 3     |
| $C_d$     | 5.5   |
| $I$       | 1     |

3.1 Analytical Procedures

In this study, permitted analytical procedures according to the MNBC, 2016 [1] are carried out to examine the structural responses and the analysis methods are as follows:

- Equivalent Lateral Force Analysis (EQLF)
- Response Spectrum Analysis (RSA)
- Linear Response History Analysis (LRHA)

Equivalent lateral force analysis is carried out to estimate the seismic design forces at any level. In this analysis, the induced base shear of the structure due to seismic excitation is calculated and it depends on the soil condition of the site, potential sources probability of seismic activity, structural properties, the total weight of the structure which includes 100% of the self-weight of the structural components, permanent weight and 25% of floor live loads. Moreover, the fundamental or natural period of the structure is also a basic factor which affects the seismic base shear. The seismic force distribution along the 10-story building is calculated manually and compared with the ETABS results and presented in figure 3.

Response spectrum analysis is similar to the equivalent lateral force analysis. Nevertheless, the response spectrum analysis should be taken into account the sufficient number of modes while the equivalent lateral force analysis is only taken into account for a fundamental period. According to MNBC, 2016, at least 90% of the modal participation mass ratio are needed to be considered in each of the orthogonal directions of the building. Moreover, the base shear of the response spectrum analysis should be rescaled to reach a minimum of 85% equivalent lateral force base shear in modal analysis. The modal participation mass ratio of the first three modes is shown in the table 4.

Linear response history analysis is performed to determine the seismic structural responses which vary with the time. The ground motion data are needed to execute the linear response history analysis. These time histories ground motion data which are the acceleration versus time input signals are selected from NGA West-2 Ground Motion Database Web and scaled according to the regional Code.
Figure 3. Lateral force to each story.

Table 4. Modal participation mass ratios

| Mode | Period (sec) | \(U_x\) | \(U_y\) | \(R_z\) |
|------|--------------|---------|---------|--------|
| 1    | 1.615        | 0       | 0.8143  | 0      |
| 2    | 1.549        | 0.8183  | 0       | 0      |
| 3    | 1.345        | 0       | 0       | 0.8197 |

3.2 Selection and Scaling of Ground Motions
In dynamic analysis, the adequate selection of ground motion becomes one of the important issues. The different ground motions can give the different structural responses. In this study, the ground motion records selection is done by using PEER West-2 ground motion database to perform linear response history analysis. The ground motion time histories are generated which have the similar ground motion characteristics as the elastic response spectra. According to MNBC, 2016, at least three ground motion time histories are needed for maximum response and average response is resulted by seven or more time histories. In this case, seven earthquake ground motions are selected to perform time history analysis according to Tall Building Initiative Guidelines, 2010 [18]. The PEER Ground Motion Database Web needs selection criteria such as tectonic type, magnitude, site to source distance, soil condition of specific site, frequency, scale factor limitation, spectral shape, maximum number of ground motion, considered period range to select the time history ground motions. The criteria to select the ground motions are as shown in the table 5. After that, the ground motion database obtained from the PEER website are scaled by mean square error within the period range of 0.2T to 1.5T and cooperated in ETABS according to the current code. The seven ground motion records resulted from the PEER Ground Motion Database and scale factors used for the analysis are shown in table 6 and table 7 for geomean response spectrum and \(S_{40d100}\) response spectrum respectively. Moreover, a set of seven bi-directional ground motion excitations for both geomean and maximum response spectra is chosen for three-dimensional analysis according to the code that is illustrated in figure 4.
### Table 5. Ground motion selection criteria

| Selection Criteria                        | Range       |
|------------------------------------------|-------------|
| Magnitude                                | 5.5-8       |
| Fault Type                               | Strike-slip |
| Closest Distance to Fault Rupture Plane  | 0.1-15 (km) |
| $V_{S30}$                                | 200-400 (m/s) |
| Intensity Measures                       | Geomean     |
| Damping Ratio                            | 5%          |
| Suite Average                            | Geometric Mean |
| Scale Factor                             | 1-4         |

### Table 6. Selected earthquake ground motions for geomean response spectra (PEER, 2010)

| No | RSN | Earthquake Name           | Year | Station Name          | $M_w$ | $R_{jb}$ | $R_{rup}$ | $V_{s30}$  | SF  |
|----|-----|---------------------------|------|-----------------------|-------|----------|----------|-------------|-----|
| 1  | 6   | Imperial Valley-02        | 1940 | El Centro Array #9    | 6.95  | 6.09     | 6.09     | 213.44      | 3.4837 |
| 2  | 165 | Imperial Valley-06        | 1979 | Chihuahua             | 6.53  | 7.29     | 7.29     | 242.05      | 3.6564 |
| 3  | 183 | Imperial Valley-06        | 1979 | El Centro Array #8    | 6.53  | 3.86     | 3.86     | 260.08      | 2.8115 |
| 4  | 864 | Landers                   | 1992 | Joshua Tree           | 7.28  | 11.03    | 11.03    | 379.32      | 2.9455 |
| 5  | 1101| Kobe_Japan                | 1995 | Amagasaki             | 6.9   | 11.34    | 11.34    | 256         | 2.1305 |
| 6  | 5825| El Mayor-Cucapah_Mexico   | 2010 | CERRO PRIETO GEOTHERMAL | 7.2   | 8.88     | 10.92    | 242.05      | 2.8933 |
| 7  | 6893| Darfield_New Zealand      | 2010 |                       | 7     | 11.86    | 11.86    | 344.02      | 3.4545 |

### Table 7. Selected earthquake ground motions for $S_{a_{RotD100}}$ response spectra (PEER, 2010)

| No | RSN | Earthquake Name           | Year | Station Name          | $M_w$ | $R_{jb}$ | $R_{rup}$ | $V_{s30}$  | SF  |
|----|-----|---------------------------|------|-----------------------|-------|----------|----------|-------------|-----|
| 1  | 183 | Imperial Valley-06        | 1979 | El Centro Array #8    | 6.53  | 3.86     | 3.86     | 206.08      | 3.4743 |
| 2  | 558 | Chalfant Valley-02        | 1986 | Zack Brothers Ranch   | 6.19  | 6.44     | 7.58     | 316.19      | 2.975  |
| 3  | 725 | Superstition Hills-02     | 1987 | Poe Road (temp)       | 6.54  | 11.16    | 11.16    | 316.64      | 3.9365 |
| 4  | 864 | Landers                   | 1992 | Joshua Tree           | 7.28  | 11.03    | 11.03    | 379.32      | 3.6399 |
| 5  | 1101| Kobe_Japan                | 1995 | Amagasaki             | 6.9   | 11.34    | 11.34    | 256         | 2.6328 |
| 6  | 5825| El Mayor-Cucapah_Mexico   | 2010 | CERRO PRIETO GEOTHERMAL | 7.2   | 8.88     | 10.92    | 242.05      | 3.5753 |
| 7  | 5829| El Mayor-Cucapah_Mexico   | 2010 | RIITO                 | 7.2   | 13.7     | 13.71    | 242.05      | 3.0943 |
4. Results and Discussion

The story displacement, story drift, story shear and story overturning moment are analyzed in ETABS, 2016 by using Equivalent lateral force analysis (EQLF), response spectrum analysis (RSA) and linear response history analysis (LRHA). These three analyses are conducted according to MNBC, 2016 to investigate the seismic structural responses. The linear response history of three-dimensional analysis is responsible by bi-directional excitation of each ground motion of the geometric mean directionality combination and maximum directionality of ground motions. The two spectra at maximum considered earthquake level are employed as target spectra to select seven ground motions from the PEER Ground Motion Database for linear response history analysis. The average responses of both geomean and maximum direction response spectra in each direction (X and Y directions) are calculated and illustrated in the following figure 5-8. The story drift increases from bottom story to the 3rd story and gradually decreases for all analyses. It can be observed that the maximum story drift occurs by $\text{Sa}_{\text{RotD100}}$ in LRHA and RSA results are the lowest in both X and Y direction. The story displacement in EQLF analysis is different around 5-10% from X and Y direction due to its change of moment of inertia. The geomean LTHA overturning moment in Y-direction is slightly lower than that of EQLF and higher above 4th story in both structures. The maximum difference of 30% and the minimum value is 10% between $\text{Sa}_{\text{RotD100}}$ and geomean definition in LTHA. The story shear in X-direction all over analyses have the same pattern with other responses and have lower difference in the mid-story levels in Y-direction. The ratio between required strength and structural elasticity, termed as response modification factor is taken as 8 in all analyses for elastic demands. The base shear of the RSA is scaled to reach the 85% of EQLF according to the code. Thus, the contribution of structural response in EQLF overestimates than that of RSA because it ignores the higher modes of the structures. Since the response spectrum of $\text{Sa}_{\text{RotD100}}$ has larger values than the geomean response spectrum, the selected ground motions also have higher spectral acceleration values for $\text{Sa}_{\text{RotD100}}$. Based on Huang et al 2008, maximum response spectral acceleration at short and 1 second period have larger values than that geomean response spectral acceleration. Thus, the larger story responses are resulted by $\text{Sa}_{\text{RotD100}}$ compared with the geometric mean time history analysis in this study. As a result, approximate overall range of 10%-30% difference is observed in both directions by LRHA for geomean and maximum direction response spectra. Thus, the amount of these differences is significant in a performing seismic analysis.
Figure 5. Story displacement from EQLF, RSA and LRHA (geomean and Sa\text{RotD100}).

Figure 6. Story drift from EQLF, RSA and LRHA (geomean and Sa\text{RotD100}).

Figure 7. Story overturning moment from EQLF, RSA and LRHA (geomean and Sa\text{RotD100}).
5. Conclusion
In this study, the effects of two horizontal definitions in ground motion selection are investigated on soft story rectangular building which is located in Mandalay city, Myanmar. Both static and dynamic analyses such as equivalent lateral force analysis, response spectrum analysis and linear response history analysis have been done to examine the seismic demand of the structures by geomean which is currently used in the Myanmar National Building Code, 2016 and $S_{a,\text{RotD100}}$ which will be used in future. The different ground motions are obtained by different MCE spectra in the selection of ground motions. In general, larger structural responses are controlled by the maximum direction definition compared to the geomean horizontal definition. The results showed the considerable effect around 10% to 30% on the response of the structure by maximum direction spectral accelerations even though MNBC, 2016 counts for geomean spectral acceleration. On the other hand, using more ground motions could capture all the variability of different characteristics of every single ground motion. Thus, it gave the option to consider the maximum response acceleration in ground motion selection and to reduce the effect of the structure in MNBC code. The consideration of maximum effect may not be economically feasible compared to the current code in Myanmar. Nevertheless, the structures should be designed in proper ways because the effect of the earthquakes may cause the structures collapse and life of people may spoil.

References

[1] Myanmar Engineering Council (2016). *Myanmar national building code*.
[2] ASCE. (2005). ASCE standard, minimum design loads for buildings and other structures.
[3] Beyer, K. and Bommer, J.J. (2006). Relationships between median values and between aleatory variabilities for different definitions of the horizontal component of motion. *Bulletin of the Seismological Society of America*, 96(4A), pp.1512-1522.
[4] Federal Emergency Management Agency. (2003). NEHRP recommended provisions for seismic regulations for new buildings and other structures. Fema.
[5] ASCE/SEI 7-16 (2016). Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers, Reston, VA.
[6] Boore, D.M. (2010). Orientation-independent, nongeometric-mean measures of seismic intensity from two horizontal components of motion. *Bulletin of the Seismological Society of America*, 100(4), pp.1830-1835.
[7] Shahi, S.K. and Baker, J.W. (2014). NGA-West2 models for ground motion directionality. *Earthquake Spectra*, 30(3), pp.1285-1300.
[8] Mayes, R. L., & Naeim, F. (2001). The Seismic Design Handbook 2nd Edition Ch. 14 Design of Structures with Seismic Isolation.

[9] Boore, D.M., Watson-Lamprey, J. and Abrahamson, N.A. (2006). Orientation-independent measures of ground motion. Bulletin of the seismological Society of America, 96(4A), pp.1502-1511.

[10] Luco, N., Bachman, R.E., Crouse, C.B., Harris, J.R., Hooper, J.D., Kircher, C.A., Caldwell, P.J. and Rukstales, K.S., 2015. Updates to building-code maps for the 2015 NEHRP recommended seismic provisions. Earthquake Spectra, 31(1 suppl), pp.S245-S271.

[11] Huang, Y.N., Whittaker, A.S. and Luco, N. (2008). Maximum spectral demands in the near-fault region. Earthquake Spectra, 24(1), pp.319-341.

[12] Thein M, Swe TL, Han S. The Seismic Zone Map of Myanmar. (2006).

[13] Thein, P.S., Kiyono, J., Win, T.T., Nu, T.T. and Aung, D.W. (2018). Seismic Microzonation of Mandalay City, Myanmar. Journal of Geological Resource and Engineering, 6, pp.1-13.

[14] Nwe ZZ, Tun KT. Seismic Hazard Analysis using AHP-GIS. Int. J. Res. Chem. Metallurg. Civ. Eng. 2016;3:1442-50.

[15] CSI, C. (2016). Analysis reference manual for SAP2000, ETABS, and SAFE. Computers and Structures, Inc., Berkeley, California, USA.

[16] ACI Committee. (2005). Building code requirements for structural concrete (ACI 318-05) and commentary (ACI 318R-05). American Concrete Institute.

[17] Haque, M., Ray, S., Chakraborty, A., Elias, M. and Alam, I. (2016). Seismic Performance Analysis of RCC Multi-Storied Buildings with Plan Irregularity. American Journal of Civil Engineering, 4(2), pp.52-57.

[18] Pacific Earthquake Engineering Research Center. (2010). Guidelines for performance-based seismic design of tall buildings. Pacific Earthquake Engineering Research Center, College of Engineering, University of California.

[19] TBI Guidelines Working Group. Guidelines for Performance-Based Seismic Design of Tall Buildings, Berkeley, California: Pacific Earthquake Engineering Research Center, 2010.