Study on Equivalent Transformation of Structural Design Parameters Based on Overseas Codes

Hongmei Ren¹, Gongsheng Peng²*

¹ Institute of Civil and Transportation Engineering, Shanghai Urban Construction Vocational College, Shanghai, 200438, China
² CCCC Logistics Planning & Design Institute Co., Ltd., Shanghai 200231, China
*Corresponding author’s e-mail: 249547410@qq.com

Abstract. With the development of the Belt and Road Initiative and economic globalization, we are going deep into the world. China's overseas engineering projects are increasing day by day, which puts forward higher requirements for structural designers. While skillfully using domestic codes and standards, designers must also understand the design codes of overseas project locations, and master the mutual transformation of basic design parameters at home and abroad. Taking a project in Pakistan as an example, this paper expounds in detail how to convert the basic design parameters of Pakistan into the design parameters corresponding to the domestic specifications, with a view to providing reference for colleagues to carry out overseas project design.

1. Introduction
The Belt and Road Initiative has been China's landmark foreign policy since it was proposed in 2013. With the development of the Belt and Road, the construction industry has opened up a new era of overseas projects. More and more projects are designed based on overseas codes, which puts forward higher requirements for the structural designers. While skillfully using domestic specifications and standards, designers must also understand the design specifications of the location of overseas projects, and master the mutual conversion of basic design parameters at home and abroad to a certain extent, so as to successfully complete the project design and pass the review of the interested parties.

The project is located in northwest Pakistan and is an industrial park project. In order to submit the design results in time, it is decided that the construction drawing design of the project is carried out in accordance with the Chinese code, but the basic design parameters are still in accordance with the Pakistan code. Due to the differences between the two countries' code systems, the basic design parameters in Pakistan's code need to be transformed equivalently before design.

2. Structural foundation selection
Based on the uncertainty of the key points and requirements reviewed by the third-party consulting company, the structural type with simple system and clear stress is preferred when selecting the single structure of the project. The independent foundation is preferred, followed by the two-way strip foundation under the column, and then the beam raft foundation. For the single body with high bearing capacity or settlement requirements, pile foundation can only be used when the shallow foundation cannot meet the requirements.
3. Main parameters of wind load

The wind load mainly depends on the design basic wind speed. When the wind load design parameters are converted between different countries, they can be converted from the design basic wind speed. Pakistan structural design code "building code of Pakistan" (SP-2007) requires that general buildings and structures must have sufficient wind load bearing capacity, and the minimum basic wind speed shall be adopted according to the specific regulations of the project location. In the absence of specific data, the minimum basic wind speed in the inland area is 120km / h (75mph) at a height of 10m above the ground, and the minimum wind speed in the coastal area is 130km / h (80mph) at a height of 10m above the ground. As the project is located in the inland, the minimum basic wind speed is 120km / h.

Compared the basic wind speed in national load code with Pakistan design code:

SP-2007: The annual probability of occurrence is 0.02, the site exposure category is \( C \), and the maximum mile wind speed \( f_{mV} \) is 10m above the ground.

National load code: The return period is 50 years, and the 10 minute average wind speed \( \bar{V}_{10m} \) is at the height of 10m on the open and flat ground.

From the definition of basic wind speed in the two countries, we can see that: (1) The return period is the same, all of which are 50 years; (2) The rough types of survey sites are the same, all of which are open and flat; (3) The measurement height is the same, all of which are 10m above the ground; (4) The measurement duration is different, Sp-2007 is the maximum mile wind speed \( f_{mV} \), while the national standard is the average wind speed \( \bar{V}_{10m} \) lasting for 10min.

The maximum mile wind speed is the maximum average sustained wind speed calculated according to the time required for a one mile long hypothetical air unit to pass through a fixed point. It does not have the concept of duration itself, and cannot directly apply the conversion method of the average wind speed of different durations in the load design manual for building structures. In order to convert \( f_{mV} \) to \( \bar{V}_{10m} \), first of all, it is necessary to convert \( f_{mV} \) to a certain period of wind speed.

Reference [6] provides equation (1) for converting the maximum mile wind speed to the 3 second wind speed:

\[
V_{fa} = (V_{3s} - 10\text{mph})/1.05
\]

Where: \( V_{fa} \) is the maximum mile wind speed (mph), and \( V_{3s} \) is the 3 second wind speed.

Table 1. Design wind speeds: ASCE 7-93 to ASCE 7-10

| ASCE 7-05 Design Wind Speed (3-sec gust in mph) | ASCE 7-10 Design Wind Speed (3-sec gust in mph) | ASCE 7-93 Design Wind Speed (fastest mile in mph) |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| 85                                           | 110\*                                          | 71                                            |
| 90                                           | 115\*                                          | 76                                            |
| 100                                          | 126                                           | 85                                            |
| 105                                          | 133                                           | 90                                            |
| 110                                          | 139                                           | 95                                            |
| 120                                          | 152                                           | 104                                           |
| 130                                          | 164                                           | 114                                           |
| 140                                          | 177                                           | 123                                           |
| 145                                          | 183                                           | 128                                           |
| 150                                          | 190                                           | 133                                           |
| 170                                          | 215                                           | 152                                           |

*Wind speed values of 110 mph and 115 mph were rounded from the “exact” conversions of 85\(\sqrt{1.6} \approx 108\) and 90\(\sqrt{1.6} \approx 114\) mph, respectively.

According to equation (1), the 3-second wind speed corresponding to 120km / h (75mph) is 88.75mph. However, in the literature cited in [6], equation (1) is not found. Therefore, this equation can be used as an auxiliary reference and should not be directly used in structural design calculations. Table 1 in reference [3] provides some specific values of \( V_{fa} \) and \( V_{3s} \). As the external reference of Pakistan design code SP-2007 is ASCE7-05, the reference value of \( V_{fa} \) corresponding to 76mph which
is close to $v_{w} = 120\text{km/h} (75\text{mph})$ is 90mph. This value is basically consistent with the calculation result of equation (1). The wind speed in 3s is converted into the average wind speed in 10min, and $v_{\text{10m}}$ is 26.7m/s. The basic wind pressure corresponding to the national load code is $w_{c} = v^{2}/1600 = 0.45 \text{kN/m}^{2}$.

4. Main parameters of earthquake

In terms of seismic design, the design principle of Pakistan structural design code SP-2007 is consistent with the American standard. According to the seismic design parameters and building safety category in the region, the seismic action is calculated under the condition equivalent to the fortification intensity. And then the seismic action is reduced according to the structural type of superstructure and seismic structural measures. After the reduction, the seismic action is involved in the load group calculation of reinforcement. In China's anti-seismic code, the seismic action used for load combination is the earthquake action calculated under frequent earthquakes. The internal force of each structural member participating in the earthquake load is amplified and adjusted according to different types and positions. And then the reinforcement is calculated according to the adjusted control internal force. Therefore, the conversion of seismic action parameters should be based on the seismic action equivalence of load combination. Therefore, the seismic action corresponding to sp-2007 reduced is equivalent to that under the national standard frequent earthquake.

According to SP-2007, static method can be used for seismic action calculation of all buildings in seismic zone 2 with use categories of 4 and 5. The seismic zone of the project area is zone 2B. According to the architectural function division in SP-2007, the use category of single building belongs to 4 categories. Therefore, static method can be used for seismic action calculation:

$$v = \frac{C_{L}I_{W}}{R_{T}} \quad \text{and} \quad 0.11C_{I}I_{W} \leq v \leq \frac{2.5C_{I}I_{W}}{R}$$

(2)

Where:

- $C_{L}, C_{I}$: seismic parameters, which can be obtained by looking up the table. In this project, $C_{L}$ is taken as 0.28, $C_{I}$ is taken as 0.4;
- $I$: Importance coefficient of earthquake action. The use of buildings of category 4 has a value of 1.0;
- $R$: The reduction coefficient of seismic action shall be determined according to the type of structure and the level of structural measures;
- $T$: Natural vibration period of basic array (s);
- $W$: Representative value of gravity load, including all dead load and part of live load.

The seismic division of the project area is zone 2B, and the use category of buildings and structures is category 4. According to the table of sp-2007, $C_{L} = 0.28$, $C_{I} = 0.4$ can be obtained by substituting equation (2):

$$v = \frac{0.4W}{RT} \quad \text{and} \quad 0.03W \leq v \leq \frac{0.7W}{R}$$

(3)

The value principle of seismic parameters is that the seismic action calculated by equation (3) is equivalent to that calculated by the corresponding parameters in the national standard seismic code under frequent earthquakes. Because the reduction coefficient $R$ under different structural types and structural measure levels is different, the calculated seismic action involved in load combination is also different. In order to obtain accurate calculate, the specific unit should be treated specifically. Taking reinforced concrete frame structure as an example, according to the classification of reinforced concrete frame in SP-2007, and comparing with the typical structural grade of seismic measures in the national standard, the reduction coefficient of seismic action can be adopted according to the common flexural concrete frame (OMRF) and the intermediate flexural concrete frame (IMRF). The higher structural grade of the frame results in the greater reduction coefficient and the smaller seismic action involved in the calculation of load combination. For OMRF frame, the reduction coefficient $R = 3.5$; for IMRF frame, the reduction coefficient $R = 5.5$.
Under the premise of meeting the functional use requirements and being safe and reliable, the project will be economical and reasonable as far as possible to reduce the project cost. In terms of the selection of each single frame type, the reduction coefficient is adopted according to IMRF for the single with more layers of superstructure, better ductility of structure, and the single with relatively low importance (such as guard rooms, watchtowers, etc.). For the single with relatively high importance (such as independent substation, independent fire pump house, etc.), the reduction coefficient is adopted according to OMRF.

For OMRF, $R = 3.5$, seismic action: $V = 0.114W/T$, and $\in (0.03W, 0.2W)$;

For IMRF, $R = 5.5$, seismic action: $V = 0.073W/T$, and $\in (0.03W, 0.13W)$.

Corresponding to OMRF and IMRF monomer, the response spectrum curve is shown in Figure 1 and Figure 2 in the range of $0.1s \sim 1.0s$ of general natural vibration period.
Compared with the 0.1s ~ 1.0s section of the seismic response spectrum curve in the national standard seismic code, it is not difficult to find that when it is equivalent to the national standard seismic code, the characteristic period is: \( T_s = \frac{0.114}{0.2} \cdot 0.57 \) s.

For OMRF, the corresponding national standard seismic parameters of the converted national standard are taken as follows: seismic fortification intensity is 8 degrees, basic seismic acceleration value is 0.2g, and the maximum value of horizontal seismic influence coefficient of frequent earthquakes is changed to 0.2.

For IMRF, the corresponding national standard seismic parameters after conversion are taken as follows: seismic fortification intensity is 7 degrees, basic seismic acceleration value is 0.15g, and the maximum value of horizontal seismic influence coefficient of frequent earthquakes is 0.12.

Figure 4 and Figure 5 are the comparison of national standard equivalent seismic response spectrum and corresponding OMRF and IMRF seismic response spectrum in Pakistan design code. It can be seen from the figure that the values of the two cases are basically the same. In the 0.1s ~ 1.0s range of natural vibration period, the maximum error of response spectrum is 5.6% for OMRF structure system and 7.7% for IMRF structure system.

5. Project example verification
There is a single floor management room and reinforced concrete frame structure in this project. ETABS design software is used to design and calculate according to the seismic parameters in sp-2007 and the design parameters equivalent to the national standard. Mode decomposition response spectrum method is used for seismic action, CQC is used for array combination, OMRF and IMRF are used for reinforced concrete frame type. The seismic action and 3D view of calculation model are Table 2 and Figure 6 respectively. The basic period of the first formation is 0.428s.
Table 2. Representative value of gravity load

| Representative value of gravity load (kN) | Dead load | Numerical value(kN) | 3877.6 | Proportionality coefficient | 100% | Live load | Numerical value(kN) | 327.6 | Proportionality coefficient | 50% |
|------------------------------------------|-----------|---------------------|--------|----------------------------|------|-----------|---------------------|--------|----------------------------|------|
| Figure 6. 3D perspective of management room

From the data in table 2, it can be seen that for IMRF and OMRF, the equivalent seismic parameters can well simulate the calculation results of Pakistan code on the numerical level of seismic action.

Table 3. List of seismic results

| Earthquake action | IMRF | OMRF |
|-------------------|------|------|
| SP-2007 GB 50011  | Ex(kN) | 1145.0 | 1145.0 |
| SP-2007 GB 50011  | Ey(kN) | 1045.0 | 1045.4 |
| Ex(kN) | 1145.0 | 727.9 | 687.0 |
| Ey(kN) | 1045.0 | 614.5 | 627.3 |

6. Summary

Based on the design process of a project in Pakistan, this project describes in detail how to convert the main design parameters of overseas codes into the design parameters of corresponding national standards in the design process, and verifies the accuracy of the equivalent calculation results with the actual single calculation results. It is hoped that the research on the conversion of design parameters at home and abroad in this paper will be beneficial to the design work of similar overseas projects.

References

[1] GB50009-2012 (2012) Load Code for the Design of Building Structures. China Architecture & Building Press, Beijing.
[2] GB 50011-2010 (2010) Code for Seismic Design of Buildings (2016 Edition). China Architecture & Building Press, Beijing.
[3] ASCE7-10 (2010) Minimum Design Loads for Buildings and Other Structures. American Society of Civil Engineers, Reston.
[4] SP-2007 (2007) Building Code of Pakistan. Pakistan Engineering Council, Islamabad.
[5] Chen J.F., Sha Z.G. (2004) Load design manual of building structure (Second Edition). China Architecture & Building Press, Beijing.
[6] Wang X.X. (2016) Study on design wind speed of a power project in Jordan. Electric Power Survey and design, (S2): 244-247.