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EARTHQUAKE RESISTANT DESIGN IN THE LOW SEISMICITY AREA - THE CASE OF KOREA -

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SUMMARY

Contrary to what has been known to the public, there are about 2400 historical earthquakes recorded for last 2000 years, and particularly, during the period from 15th century to 18th century, exceptional seismic activities were recorded in Korea. Therefore, it is widely recognized in Korea that now is the time to prepare for the protection from earthquakes and a new earthquake resistant design code has been developed and enacted for the first time in Korea. This paper describes the background, and some provisions of the new code in the form of Building Law, Building Law Enforcement Ordinance and Detailed Regulations.

INTRODUCTION

Korea has long been known as a country of low seismicity. Consequently, little attention has been given to the earthquake resistant design so far except some nuclear power plants built recently in Korea. The historical earthquake records of Korea, the first of which is dated as early as 27 AD, indicates that Korea can never be a earthquake-free zone and needs some measures of earthquake disaster mitigation as the potential earthquake disaster increases as the concentration of urban population and the construction of large and tall buildings are being expedited recently in Korea. The introduction of the earthquake resistant design code would be the most practical measures to take. With the government initiative, the earthquake resistant design code has been introduced in 1988 first time in the Korea's history.

There are, however, a number of problems in introducing new earthquake resistant design code. First of all, finding experts in earthquake engineering who would participate in developing the code was a very difficult task because the earthquake effects have been neglected for such a long time and only a limited number of structural engineers and researchers, mostly educated abroad, have had some experience in earthquake resistant design. It was also another difficult task to justify the additional construction cost due to the earthquake resistant design and obtain the public support as the probability of earthquake occurrence in Korea has been known to be very low and there is only limited reliable instrumental earthquake data available to emphasize the necessity of earthquake resistant design.

Based on the recommendations prepared by the earthquake resistant design research group, an ad hoc committee established in the Architectural Institute of Korea, the new code has been developed and enacted with the initiatives of the Ministry of Construction, Korea. The code provisions were carefully written to minimize the impact on the national economy and to be easily understood by the practicing engineers in Korea.

EARTHQUAKE ACTIVITIES IN KOREAN PENINSULA

The historical earthquake records of Korean peninsula are found in many historical literature. As shown in Fig. 1, about 2400 historical earthquakes have been recorded during the period of last two thousand years and among those earthquakes, about two hundred are estimated to be greater than intensity VII as the MM intensity(Refs. 3,6).

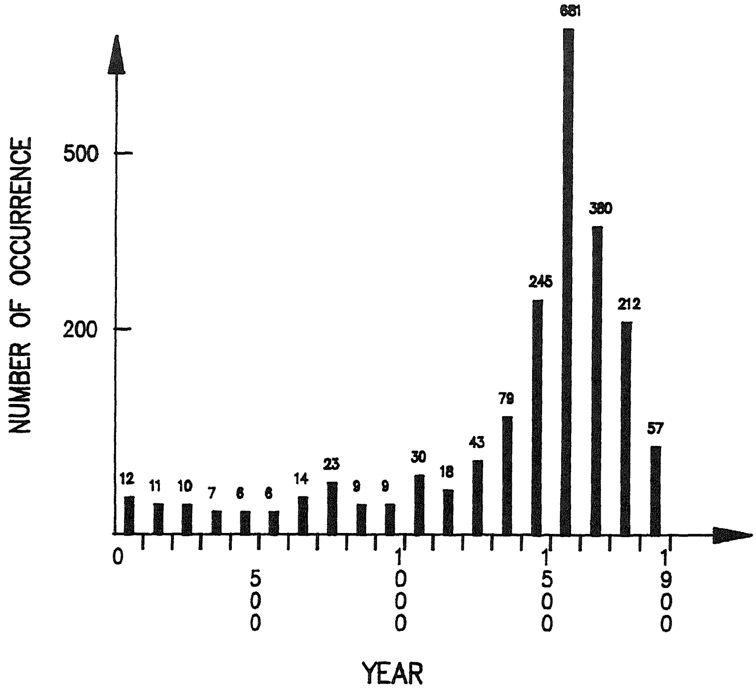

Fig. 1 The Historical Earthquakes in Korea Peninsula

Most of the historical earthquakes of Korea had been recorded in the densely populated areas such as the capital cities and their vicinities. Therefore, many of earthquakes in the remote areas may have not been recorded because of the lack of proper transportation and communication systems at that time. Among the severe historical earthquakes of Korea, the one occurred in Gyeongju, the capital city of Shilla Dynasty, in 779 AD was accompanied the highest losses ever recorded ; killing about one hundred people.

As seen in Fig. 1, exceptionally vigorous earthquake activities in Korean Peninsula recorded during the period from 15th to 18th century may deserve special attention. This implies that the number of earthquake felt by human being during the period were about 1500, i.e., about four times the normal rate per year, and the released energy during the period was estimated as about a half the total energy released in Korean peninsula since the first earthquake was recorded in 27 AD.

After two centuries' vigorous activities, the seismic activities in Korea have been calmed down for another two centuries. The later two centuries are presumed as seismic gap by seismologists and there are some worries that it may be nearing the end of the gap and the accumulated energy during the period may be released soon causing some strong earthquake activities in Korea again.

Since the opening of the 20th century, when the first seismograph was installed in Inchun 1905, there are four major earthquakes recorded in the Korean peninsula of which magnitudes were equal or greater than 5.0 as given in Table 1.

Table 1. Major Earthquake Occurred in Korea

Region	Date	Magnitude	Remarks
Ssanggesa	July 4, 1934	5.0	
East Sea	September 6, 1968	5.4	
Mt Sokli	September 15, 1978	5.2	
Hongsung	October 7, 1978	5.0	

After all said, Korea is still an area of the low seismicity where some exceptional vigorous earthquake activities had been recorded in the past and, as some worry, there may exist a certain probability of potential earthquake occurrence in the future. Thus, introducing some measures of protection from the potential earthquakes is needed.

INTRODUCTION OF EARTHQUAKE RESISTANT DESIGN CODE

There is no need to reiterate the importance of the design against the earthquake in the strong seismic area. In the low seismic area, however, the extra construction cost for the protection from earthquakes should be within the justifiable range and acceptable by the public. It should be the society concerned who decide if they need a seismic resistant design codes to have certain level of protection from earthquakes or they would accept the some level of damage in case of earthquake.

Early suggestions by some of the engineers that, instead of writing new codes, some of the provisions in the widely recognized codes such as UBC should be temporally used have been rejected by the majority of the engineers because earthquake resistant design procedures are different from a country to another and it is difficult to transfer the code of a country to another. In order to stipulate the earthquake resistant design procedures in Korea, instead of writing an entirely new design code, the current Building Law, Building Law Enforcement Ordinance and Detailed Regulations have been revised effective as of January 1988 with the initiative of Ministry of Construction.

BASIC STRATEGIES OF THE NEW CODE

Based on the recommendations provided by the Architectural Institute of Korea which conducted basic research for the Ministry of Construction before their revising the existing Laws and Regulations, the following basic concepts of earthquake resistant design has been developed and stipulated in new codes(Ref. 2).

1) Considering the current state of earthquake resistant design technology in Korea and the fact that the code is constituted for the first time in Korea, the design procedures should be simplified to a great extent. Thus, the application of more sophisticated and complex technologies such as the dynamic analysis and the consideration of P-Δ effect, etc., that make unskilled structural engineers troublesome, are not included but substituted with more simplified methods such as the static equivalent analysis. The code can be improved as the practicing engineers become more experienced in earthquake resistant design in the future.

2) In order to avoid any serious impact on national economy, the scope of application of the first code is narrowed down to the important buildings such as buildings which have 6 floors or more, assembly hall, hospitals, communication centers, etc.

SOME PROVISION IN THE KOREAN CODE

1) Base Shear

As do many other earthquake resistant design codes around the world(Refs. 1,4,5), the new Korean seismic design code utilizes the static equivalent analysis techniques, in which computing the base shear is the fundamental part and obtained by the following equation.

$$V = \frac{A\ I\ S\ C}{R}\ W \tag{1}$$

where, V = base shear, A = seismic zone factor, I = importance factor, C = dynamic coefficient, S = site coefficient for soil characteristics, R = response modification coefficient, and W = effective weight of structure.

Seismic Zone Factor The seismic map in Korean code which is divided into three zones as shown in Fig. 2 and the zone factors which are directly related to the maximum effective ground acceleration and were decided based on the historical and instrumental seismic records are given in Table 2.

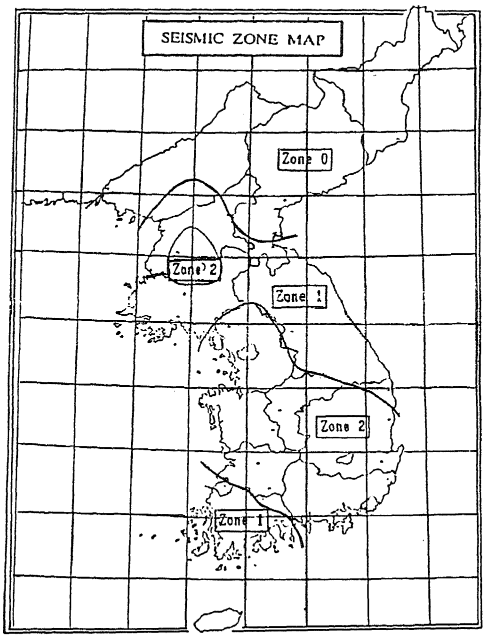

Fig. 2 The Seismic Zone Map in Korea Peninsula

Table 2. The Seismic Zone Factors

Zone	0	1	2
A	-	0.08	0.12

Table 3. The Importance Factors

Importance	3	2	1
urban area	1.0	1.2	1.5
rural area	0.8	1.0	1.2

Importance Factor The importance factor has to do with the degree of hazard to human life that the failure of the building might cause, imposing greater design forces for some classes of occupancy than for others. In Korean code, different factors are applied to the city planning area and rural area reflecting the fact that the same ground shaking may cause more damage in the population concentrated urban area.

Natural Period and Dynamic Coefficient The natural period of the structure is needed to decide the dynamic coefficient. Both natural period and dynamic coefficient are obtained in a similar manner to UBC and given as follows.

$$C = \frac{1}{1.2\sqrt{T}} \quad (C\ S \le 1.75) \tag{2}$$

Table 4. The Natural Periods

$T=0.085h^{3/4}$	for steel moment-resisting frame
$T=0.06h^{3/4}$	for RC moment-resisting frame
$T=0.09h/L^{1/2}$	for all other buildings

Soil Factor To consider the earthquake effects of soil characteristics, the site coefficients are classified into three categories as given in Table 5.

Table 5. The Soil Factors

Soil Type	S1	S2	S3	S4
S	1.0	1.2	1.5	-

Response Modification Coefficient This factor is to take into account the non-linear behaviors and damping effects of the structure. The factors in ATC 3-06 has adopted in the code with some modifications.

2) Vertical Distribution of the Base Shear

The vertical distribution of the base shear is decided by the following equations in the Korean code.

$$F_x = \frac{W_x h_x^k}{\sum_{i=1}^{n} W_i h_i^k} V \tag{3}$$

where

k=1.0, if $T \leq 0.1$ sec,
k=1.5, if $1.0 < T \leq 2.0$ scc
k=2.0, if $T > 2.0$ sec

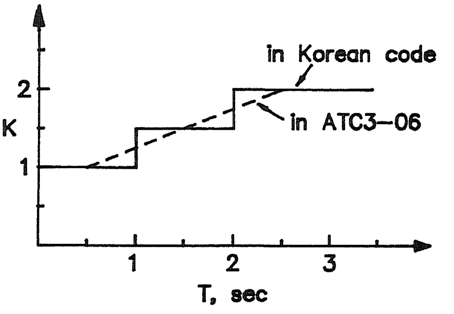

Fig. 3 The Comparison of K Value

3) Other Provisions

Horizontal Torsional Moment and Accidental Torsional Moment The torsional effects of earthquake forces are considered in the seismic design of a structure with eccentric mass distribution and the additional accidental torsional moment is also determined by assuming that the mass is displaced from the calculated center of mass in each direction a distance equal to five percent of the building dimension at that level perpendicular to the direction of the force under consideration.

Overturning Moment At any level, the overturning moments to be resisted are determined using those lateral seismic forces (F_x) which act on levels above the level under consideration as following equation. The reduction factor is applied in order to take into account the fact that the lateral seismic forces under consideration may not be imposed at once.

$$M_x = \rho \sum_{i=x}^{n} F_i (h_i - h_x) \tag{4}$$

where

for top 10 stories	$\rho = 1.0$
top 11 - 19 stories	interpolated
below the top 20 stories	$\rho = 0.8$

P-Δ Effects and Story Drift Limitation P-Δ will increase the member forces and story drifts. In Korean code, however, this effect is not taken into consideration but the story drift is constrained to less than 1.5 % of story height.

Architectural Consideration Adjacent structures should be located away from each other by two times the sum of the deformation of adjacent structures. Some provisions for the non-structural elements and the architectural equipments are also included in Korean code.

More Sophisticated Analysis For the important structures such as tall buildings, and structures with irregular configuration, a more sophisticated analysis methods such as modal analysis, mode superposition method and direct integration method, are implicitly recommended to use.

CONCLUDING REMARKS

Korea now has its first version of earthquake resistant design code parts of which are based on the research done elsewhere. By the introduction of the code, Korea is no longer earthquake free zone for the design and construction of building structures as stated by the established law and enforcement.

The newly established code is expected to have significant effect on the general improvement of building construction and stimulate researches in the once neglected area, i.e., earthquake engineering. The code itself is also expected to be improved as the general earthquake resistant design technology in Korea progresses.

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