The Re-evaluation of the Potential Seismic Hazard in Relation to Nuclear Power Plants of Korea

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Abstract

The seismic hazard of the southeastern part of the Korean peninsula is re-evaluated in relation to safety of nuclear power plants. We take into account two main factors such as seismic hazard with active faults and tsunami occurrences. Major seismic hazard re-evaluation is performed by mechanism of earthquakes and relocation of active faults including tsunami phenomena. The basic relationship between an earthquake strong motion in terms of gravity (g) and magnitude is clearly demonstrated for an earthquake resistant design in nuclear power plants. At present we are operating 23 nuclear power plants and we will increase more nuclear power plants in the next decade. Nevertheless the nuclear power plants in the southeastern part of Korea are not free from seismic hazard in the light of recent seismicity - Pohang Earthquake on April 15, 1981 (M=5.3), Yeongwol Earthquake on May 29, 2004 (M=5.2) and Mt. Odae Earthquake on January 20, 2006 (M=4.8), including many large historical earthquakes in the Gyeongju area which gave severe damage to houses and loss of people in the Shilla Dynasty. The compelling reason of this study is to suggest the seismic hazard re-evaluation in relation to the over-saturated spent fuels as well as nuclear power plants in order to reduce the seismic disaster from the forthcoming earthquakes.

Key words: focal mechanism, paleo-earthquake, tomography, acceleration, SSE, OBE, gravity, tsunami, spent fuel

1. Introduction

The Korean peninsula is located at the margin of the Eurasian Plate which is also at the merging of the Amurian Plate-aka Baikal-Korea Plate (Kim et al., 2004), the Pacific and Philippine Sea Plates. The Korean peninsula remains safe between two highly seismic zones of intra-continental earthquakes in China and inter-plate earthquakes in and around Japan. The great change in evolution of the crust in the broad region of the peninsula was just Middle Mesozoic era, but the northeastern part of the Korean peninsula that is related to the subduction zone of the Pacific plate under the Eurasian Plate had developed the continental crust during the Archean to the Lower Proterozoic. The deep magmatic activities and faulting movements were more intensively generated, especially in the Rangnim Massif. Subsequently
the crust also changed its appearance due to the neo-tectonic movement. The distribution of earthquakes in the peninsula is closely related to geological structures formed during the past geological times. In particular the young fault structures are more relevant to epicenter of instrumental earthquakes. Present studies show that the seismicity of the southern part is higher than that of the northern part in the peninsula. According to historical literature, the seismicity of the Rangnim Massif (Pyeonganbuk province) and Mt. Baekdu volcanic zones are remarkably weaker than the other region. Most of earthquakes are generally accompanied by the movements of NE-SW (NW-SE) trending faults suffered from both of NEE-SWW trending compression stress and NNW-SSE trending tension stress. The Korean seismicity is low in the light of size and frequency of earthquakes as compared with China and Japan. However we have experienced large historical earthquakes according to historical literature and recently we often observe the intermediate-size of earthquakes in and around the Korean peninsula with the severe earthquake disaster in the vicinity (Chiu and Kim, 2004). So it is of great significance to reassess the seismic hazard in relation to the nuclear power plants and the radioactive waste disposal facilities because they are located in the potential seismic risk zone.

2. Focal Mechanism and Relocation of Earthquakes in Korea

Focal mechanisms of earthquakes in and around the Korean peninsula were analyzed using moment tensor inver-

Fig. 1. Seismotectonic Map in and Around the Korean Peninsula. Fault System and Focal Mechanism of Major Earthquakes by Moment Tensor Inversion are Presented with Epicenters (Closed Square) Relocated Based on hypoDD Method (Pak, 2007; Kim 2007).
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sion (Kim and Kraeva, 1999; Kim et al., 2000) which is more efficient than the conventional method based on the polarity of the first motion of P-wave arrivals because it is possible to use one single station or a few stations instead of requiring many stations for the conventional focal mechanism using the first motion of P-wave arrivals. According to the focal mechanism of recent intermediate size earthquakes, the focal mechanisms of most earthquakes in the Korean peninsula are found to be strike-slip motions, except for some normal faults in the Baengnyeong-do and Sariwon area and a few Reverse faults in the East Sea (Fig. 1). This focal mechanism map (Fig. 1) indicates the tectonics and the active fault system in the Korean peninsula.

In the aspect of focal mechanism, it is evident that most of Korean earthquakes are associated with intra-continental earthquakes which may be due to local tectonic forces rather than global tectonic forces. The application of the double-difference algorithm (hypoDD) to relocation of epicenters is very important to investigate the relationship between earthquake hypocenters and active faults in the Korean peninsula because earthquakes would occur along the active faults (see Fig. 1). The instrumental earthquakes of 557 in and around the Korean peninsula from 1978 to 2005 were used to relocate the hypocenters of earthquakes using hypoDD (Pak, 2007). The earthquake data were obtained directly from waveforms provided by KMA (Korea Meteorological Administration), KIGAM (Korea Institute of Geoscience and Mineral Resources), KSI (Korea Seismological Institute), and indirectly from bulletins from CEA (China Earthquake Administration), JMA (Japan Meteorological Agency), NIED (National Research Institute of Earth Science and Disaster of Japan), Seismological Institute of DPRK, ISC (International Seismological Centre), IRIS (Incorporated Research Institutions for Seismology) and USGS (United States Geological Survey).

The star represents the Gyeongju Earthquake on June 26, 1997 (Mw=4.7). The movement of the Quaternary along the Yangsan Fault and the Ulsan Fault is found by an outcrop or a trench (Seo et al., 2009; Kyung, 2010). Seo et al. (2009) stated that the Ulsan fault as well as the Yangsan fault which runs in the NNE direction with about 200 km in length as the active faults of the Quaternary faulting from field evidence efforts of geological, geochronological, seismological and paleoseismological studies (Seo et al., 2009). Kyung (2010) also found that the dominant faulting characteristics of the Yangsan and Ulsan faults are right-lateral strike-slip with reverse faults which agree with the focal mechanism of recent earthquakes along these fault zones. Kyung (2010) estimated the maximum paleo-earthquake at 6.8 and 7.0 in the Yangsan and Ulsan faults respectively based on the relationship between displacement and magnitude (see Fig. 2). The youngest part of southern Korea, the Gyeongsang Geosyncline is located in the southeast of the peninsula and was formed during the Cretaceous Period. We should note that all nuclear power plants (Kori, Wolsung and Uljin) are close to the active faults within 30 km. Some experts found an active fault underneath the Tsuruga nuclear power plant (No. 2) located in west Honshu in Japan and said that it could trigger an earthquake and lead to an accident. So Tsuruga’s No. 2 reactor now faces indefinite stoppage or likely decommissioning unless its operator provides new data overriding the experts’ decision. The experts also mentioned the potential risk of the spent fuel storage pool at Tsuruga’s No. 2 reactor in case of a major earthquake. The potential danger of earthquakes notwithstanding, we are operating Kori, Wolsung, and Uljin nuclear power plants in the active fault zones. It is very necessary to update the safety assessment of nuclear power plant in this region and the authority should do what to do.

### 3. Seismic Tomography for an Active Fault and 3D Earth Structure

#### 3.1 Local Tomography and Active Fault

Seismic tomography is one of most important techniques to investigate the earth crustal structure and active faults because we can obtain the large amount of digital seismic data from a number of deployed seismic stations nowadays.
Recently local tomographic models were intensively studied in the central and southern Korea using the regularized small blocks for high resolution (Kim and Li, 1998). The larger database of P- and S-wave travel time arrivals in the whole of the Korean Peninsula was also applied to 3D velocity tomography of the Korean peninsula with large scale for post-seismic sites (Kim and Bae, 2006). We found that the tomography of low velocity anomalies for P- and S-wave (Kim and Bae, 1996) well corresponds with the small scale tomography of high resolution (Kim and Li, 1998) beneath the Gyeongju Earthquake area. Here we show the high resolution of small block scale in Fig. 3. The tomography study can help better understand the crustal structure and the faulting process because we can visualize the fault system in more details. Fig. 3 shows the seismic tomography of the Gyeongju Earthquake of June 26, 1997 (M=4.7) in terms of P-wave velocity anomalies (Kim and Li, 1998) and the density tomography based on Bouguer gravity anomalies which was produced by VIRG (Rudgeofizika-Exploration Geophysics Institute, St. Petersburg, Russia) during the author’s stay (SGK) in 1996. The thick curved and thick curved dashed lines on the upper in Fig. 3 clearly reveal that the detached fault and the potential active fault in the deep structure in the high resolution tomography. The thin and thick lines on the lower figure represent the observed values and calculated values of Bouguer gravity anomalies above the hypocenter and fault area. The active fault associated with the seismic source is evidently shown with a fault length of 16-50 km beneath 10 km from the surface. If we assume that the fault length is 16 km, the seismic magnitude is about 7.0 using Bolt’s formula (Bolt, 1978), which corresponds with the paleo-seismic magnitude estimated by Kyung (2010). Gyeongju is within 30 km from the Yangsan and Ulsan faults. The epicenter of Gyeongju Earthquake is near the cross point of the Yangsan and Ulsan faults, especially along the Ulsan Fault. According to USNRC (U S Nuclear Regulatory Commission), the capable fault (active fault) with over 16 km fault length should be avoid within 160 km from the nuclear power plant sites. The capable fault (active fault) is defined as the displacement movement took place either at least once during last 35,000 years or displacement repeated during a half million years on surface or near vicinity. The empirical magnitude can be obtained using observed fault length (L), displacement (D) and area (DL) (Kim, 2008). For example, Bolt (1978) used $M_L = 6.03 + 0.76 \log (\text{fault length})$, using his formula we could estimate the maximum potential earthquake in this zone at about 7.0. If we want to use the maximum potential

![Fig. 3. Seismic Tomography (Upper) and Density Tomography (Lower) Based on Bouguer gravity. The Thick Solid and Dashed Lines Indicate an Active Fault and a Potential Active Fault. The Thin and Thick Lines in Lower Image Represent Observation and Calculation Bouguer Gravity Anomalies. The Star Indicates the Location of Gyeongju Earthquake of June 26, 1997 (M=4.7).](image-url)
earthquake for SSE (safe shutdown earthquake) and OBE (operating basis earthquake) in terms of magnitude, we should reinvestigate the relationship between fault length (L), displacement (D) or surface rupture length and fault area (DL) using all historical earthquakes as well as instrumental earthquakes and various formulas (Bolt, 1978; Bonilla et al., 1984; Wells and Coppersmith, 1994). It is suggested that we re-evaluate the maximum potential earthquakes for nuclear power plants of Kori (5), Wolsung (4), and Uljin (6) as well as Gyeongju radioactive waste disposal facilities including high-level nuclear spent fuel which cannot be excluded from seismic risk and urgently need to make up for the weak points in the seismological examination by 2020 when the spent fuel storage would be expected to be fully over-saturated.

3.2 The Tectonic Features of the Upper Mantle Structure in the Far East by Global Tomography

It is of great significance to show the seismic hazard of the Korean Peninsula using regional tectonics from regional tomography in and around the Korean Peninsula. Here, we used three teleseismic phase P, pP and pwP for tomographic purpose. For the teleseismic deep phases these epicenter distances larger than 25°, the travel time residuals of P, pP and pwP were -3.5→3.5 sec and -7.5→7.5 sec for the regional phases epicenter distances smaller than 25°. For the model parameterization we select the following layers in this upper mantle study: 0-35, 35-70, 70-120, 120-230, 230-290, 290-350, 350-410, 410-470, 470-530, 530-595, 595-660, 660-760, 760-860, 860-980, 980-1100 km. The smallest size of cell is 0.6°×0.6°×35 km, generally the cell dimensions vary from 0.6°×0.6°×35 km up to 2°×2°×100 km in the upper mantle. In the upper mantle at least 500 compose rays per regular cell.

In this study we strove to illustrate the upper mantle heterogeneity on a small scale, in which smallest scale of the cells is 0.6°, and improve the recent global model parameterization in global tomography a step further. Furthermore, we aim to resolve lower mantle structure with smallest cells of 1.2°-3°. We thereby expect to fully exploit the resolving power of the available seismic data in the entire mantle volume. Here, we used three teleseismic depth phases P, pP, pwP of P wave, which are recalculated for the reference Earth model (Kennett et al., 1995). For the model parame-
terization with cells of variable sizes we adopted an upper mantle inhomogeneity of the earth.

We illustrated upper mantle heterogeneity beneath major subduction zones of the region Far East, and it revealed following results about major subduction zones: high velocity Pacific slab is continuously penetrating the Japan Island and the East Sea of the margin of the Eurasian Plate westward with a dip angle of about 30°. There is an inactive seismic zone at the depth of 200-350 km beneath the East Sea and the seismic activity ends at the depth of about 600 km. We also found two high velocity groups at the end of the Pacific slab, i.e. at the depth 660 km discontinuity and 410 km discontinuity underneath the Korean Peninsula and the East Sea, the descent slab ends at the depth of about 700 km beneath the boundaries between North Korea, China and Russia. We found the subducting slab to be broken at around 400 km depth, except for maximum pressure axis of descending pacific plate near 40°N of latitude and to be no subducting slab of the Pacific Plate along 35°N. The 410 km discontinuity is well revealed off the Pacific Plate along 135°E in the oceanic lithosphere. The global tomography indicates that most of inter-plate earthquakes do not occur just beneath the Korean peninsula, but do occur beneath the Japan Islands and the Pacific Ocean.

4. Strong Motion Data and Spectra Applied to Nuclear Power Plants

According to U.S. Nuclear Regulatory Commission (USNRC), the capable fault (active) is defined as a fault has activated a displacement either at least once for last 35,000 years or has reactivated it within a half million years. The nuclear power plant site should avoid the capable fault whose fault length is greater than 16 km within 160 km from site according to USNRC. The magnitude of Mt. Odae Earthquake (M=4.8) is less than that of Gyeongju Earthquake (M=4.7) by 0.1 unit, but it is worthwhile to discuss about acceleration in more details with other strong earth-
quake data since the Mt. Odae is the only first largest earthquake with digital data. Furthermore the imminent reason is that we have found the large fault beneath Gyeongju area to have the potential active fault which may generate large earthquakes equivalent to magnitude 7.0. Therefore it is necessary to reinvestigate whether or not the fault beneath Gyeongju is an active fault which will bring about the havocing earthquake in the vicinity to nuclear power plant sites.

4.1 Strong Motion of Mt Odae Earthquake

The strong motion digital data of Mt. Odae Earthquake of January 20, 2007 was obtained at an epicentral distance of 8 km, DGY (Daekwanryeong) station. The source parameters of the earthquake are as follows:

- Origin time: 01/20/2007 20:56:53.6 (KST)
- Location: 37.6889°N, 128.5841°E,
- Focal depth: 10 km
- Magnitude: 4.8

3-component acceleration of 3-component DGY (Daekwanryeong) station

<table>
<thead>
<tr>
<th>Component</th>
<th>PGA (gal)</th>
<th>PGV (kine)</th>
<th>PGD (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
<td>63.5</td>
<td>1.30</td>
<td>0.048</td>
</tr>
<tr>
<td>NS Component</td>
<td>152.7</td>
<td>-2.45</td>
<td>-0.124</td>
</tr>
<tr>
<td>EW Component</td>
<td>129.3</td>
<td>-3.12</td>
<td>-0.148</td>
</tr>
</tbody>
</table>

Sum of two vectors PGA = $\sqrt{(152.7)^2+(129.3)^2}$ = 200.09 gal
Sum of three vectors PGA = $\sqrt{(152.7)^2+(129.3)^2+(63.5)^2}$ = 209.92 gal

The maximum ground acceleration of NS component is 152.7 gal (0.153 g) at a site which is about 8 km away, but sum of two vectors is close to 0.2 g. Referring to the maximum ground acceleration, we should consider magnitude, distance and geological condition as well as construction structure. So in the engineering point of view, it is more reasonable to say acceleration rather than magnitude concerning safety for a nuclear power plant.

We examine several earthquakes in terms of acceleration and tripartite logarithm plot.

We also estimate the maximum pseudovelocility (around 4-5 cm/s), maximum acceleration (120-150 gal) in the azimuth of 45 degrees, maximum displacement (0.12 cm) in the azimuth of 135 degrees at 0.2 s of period in the horizontal component on the Tripartite Logarithm Plot, which will be

![Fig. 6. The Tripartite Logarithm Plot of Response Spectra. a. Acceleration of 3-component at DGY Station, b. Its Pseudo Response Spectrum (Damping Coefficient=5%)](image-url)
a basis for the earthquake resistant design for nuclear power plants in engineering seismology (Fig. 6). We can utilize an earthquake response spectrum (standard response spectrum) using the tripartite logarithm plot for the basic earthquake resistant design for the nuclear power plants.

The maximum acceleration of the Mt. Odae at DGY station is 152.7 gal from the N-S component which may be contaminated by noisy signals, while 129.4 gal from the E-W component. However accelerations for both components are almost the same in the frequency domain of the response spectrum with only difference of the period (0.15 s) because of damping (5%) of high frequency for the N-S component. The total sum of two horizontal vectors and sum of three vectors are 200.09 gal and 209.92 gal, respectively which are close to 0.2 g. The acceleration of Mt. Odae is the largest acceleration recorded since the accelerometers were deployed. The actual g value of nuclear power plants in Korea is designed as 0.20 g but Bugu site (Uljin nuclear power plant) whose value is 0.256 g reported from KHNP (Korea Hydro & Nuclear Power Co.). Overall the anti-earthquake design to nuclear power plants in Korea are close to the maximum earthquake much less than 6.0, indicating that it may be close to 5.0-5.5 in Richter magnitude which may be considered as the maximum instrumental earthquakes in the southeastern part of the Korean peninsula. Therefore it is not correct that 0.2 g is equivalent to an earthquake of Richter magnitude 6.0. KHNP (Korea Hydro & Nuclear Power Co.) insists that the existing nuclear power plants in operation were designed to resist earthquakes as high as 6.5 on the Richter scale and the new design of nuclear power plants, including the Singori Nuclear Power Plants No. 1 and 2, were designed to resist earthquakes reaching M=6.9, but it was wrong. The anti-earthquake design for Korean nuclear power plants corresponds to 5.0-5.5 of Richter magnitude which is close to a maximum instrumental earthquake in Korea.

4.2 New Zealand Earthquake
Origin time: 02/21/2011 23:51:43 (UTC)
Epicenter: 43.600°S, 172.710°E
Focal depth: 5 km
Magnitude: 6.3
Casualty: 182
Acceleration at an epicentral distance of 8 km, REHS (Christchurch Resthaven)
S88E PGA = 705.0 gal, N02E PGA = 364.1 gal, Up PGA = 512.4 gal
Sum of 2 vectors PGA = 793.47 gal
Sum of 3 vectors PGA = 944.54 gal (see Fig. 7).

4.3 Japan NE Great Earthquake (The Tohoku Great Earthquake)
Event: 2011/03/11 14:46 Off Sanriku (M=9.0, h=24 km)
Station: Tohoku University (THU)
Instrument: SMAC-MD
Sensor places: 01F
Epicentral distance: 177 km (almost the same distance as Fukushima nuclear power plant)
Azimuth 192 degree: PGA=330 gal
Azimuth 282 degree: PGA=330 gal
Up: PGA=214 gal
Sum of 2 vectors: PGA=466.69 gal
Sum of 3 vectors: PGA=513.42 gal
Seismic intensity: 5.6 (at 01F)
Record length: 321 sec.

As we see, we found that the maximum acceleration at a site of about 180 km from the epicenter (Fukushima Nuclear Power Plant) is 0.33 g on the horizontal component even if it is far away since it is a large earthquake with magnitude of 9.0 (see Fig. 8). So we cannot neglect the epicentral distance because an earthquake intensity (damage) is a function of magnitude, distance and geological including construction.

Fig. 7. Acceleration and Pseudo Response Spectra of 3-component of New Zealand Earthquake of February 20, 2011 at REHS Station, New Zealand. As We See, We Obtained 705.0 gal (0.7 g) of Maximum Acceleration from the Magnitude 6.3 at a Distance 8 km.
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However, the main cause of catastrophe for Fukushima Nuclear Power Plant was due to the tsunami intrusion, even if the earthquake-resistant design of Fukushima Nuclear Power Plant had all its units ranged 412 gal to 452 gal.

5. Tsunami Disaster and Cause in the East Coast of the Korean Peninsula

The tsunamigenic earthquakes occur along the East Sea block boundary (aka the Amurian plate boundary) near offshore west Hokkaido and NW Honshu. The focal mechanisms of these earthquakes show the dip-slip motion with east-west P-axis. It is not sure whether or not these tsunamigenic earthquakes are the interplate earthquakes along the boundary between the Amurian plate and the Japan island arc combined with the North American plate and the Pacific plate. It is well-known that most of tsunamigenic earthquakes are shallow-focus earthquakes (focal depth ≤60 km) whose magnitudes are greater than 6.3 and whose typical focal mechanisms are found to be a dip-slip type (reverse or normal faulting). It is also required that the ocean depth should be deep enough to generate the water column. Most of tsunamigenic earthquakes west Hokkaido and NW Honshu due to dip-slip motion of East Sea Thrust (Back-arc Spreading Theory) in the north of the East Sea (Kim, 1984).

The cylindrical solitary waves propagate through the deep East Sea (3500 m) and Sikhote Yamato Rise including reflection off Najin reach the southeastern coast of the peninsula. In Fig. 9, the source areas of major tsunamigenic earthquakes are displayed in the East Sea. Most of these earthquakes are related to the reverse fault types in the back-arc of the neo-tectonics in this region. The bathymetry of the East Sea is normally deep (3500 m), particularly the northern half of the sea is very deep whereas the southern half of it is composed of the Yamato Rise and shallow depth (Kim, 1984).

The tsunamis reflected from the vertical wall of the North Korean coast and the Sikhote-Alin continental slope propagate as cylindrical solitary waves and are focusing at the southeastern Korean coast. It is found that the tsunami disaster in the southeastern coast is always more severe than any other place, implying that Uljin nuclear power plant is not free from the tsunami disaster. Especially, the rapid increase of tsunami velocity is due to a steep continental slope of the southern coast of the East Sea and the geometry of the site. For example, we can say that the Japan NE great earthquake (M=9.0) of March 11, 2011 generated a large
tsunami height (around 14 m) resulting in the catastrophe to the Fukushima nuclear power plant because the coastal continental slope is steep along the deep trench (around 7000 m depth) and the site was also located on the headland at which the wavefronts of tsunamis would be concentrated. That is the main reason why Fukushima nuclear power plant experienced the catastrophe of tsunami whereas Onagawa nuclear power plant was safe owing to its location along the bay (see Fig. 10).

The tsunami waves propagate perpendicular to the wavefront that is almost the same as the bathymetric distribution (Fig. 10). So it is very important to note that the rays of tsunami propagating perpendicularly to the bathymetry may strongly converge to a headland or cape of the protruded southeastern coast of the Korean peninsula.

The velocity of tsunami is function of gravity and depth of the ocean, i.e. $C = \sqrt{gh}$ since $\tanh (kh) \approx kh$, as $(kh) < (\pi/2)$, where $g = 9.8$ m/s, $k =$ wave number, $h =$ ocean depth. Therefore the velocity of tsunami in the deep ocean is very high and getting lower as it approaches the coast, but the kinetic energy increases because of the conservation of total energy in physics.

It takes about two hours for the tsunami occurred near west Hokkaido or NE Honshu to reach the southeastern coast of the Korean peninsula (Fig. 11).

The primary reason of the tsunami havoc to Fukushima Nuclear Power Plant is that the nuclear power plant was located at the protruded coast as compared to Onagawa Nuclear Power Plant being located in a bay which could avoid the tsunami devastation and the plants reactors shut down without damage and all safety systems functioned as designed, despite it being the closest nuclear power plant to the epicenter of the earthquake and tsunami than the stricken Fukushima nuclear power plant. Here we have to take into account the tsunami disaster for our nuclear power plants — Wolsung, Uljin and Samcheok (planning) — which are similar to Fukushima nuclear power location in relation to the geomorphological location.

6. Seismic Hazard Surrounding the Nuclear Power Plant Sites

Our studies also suggest that large deep-focus earthquakes in and near the Korean Peninsula would trigger some large earthquakes in this seismic regime. Large deep-focus earthquakes in the subduction zone backside hold large energy enough to simulate tectonic strain release of the seismic regime of the East Sea. We note that Kobe earthquake of January 16, 1995 (M=6.9) and Sakhalin Neftegorsk earthquake of May 27, 1995 (M=7.5) were followed by two large deep-focus earthquakes of January 19, 1993 (M=6.6) and July 21, 1994 (M=7.3) in the East Sea. Almost at the same time two Korean earthquakes, Yeongwol earthquake of December 13, 1996 (Mw=4.8) and Gyeongju earthquake of June 26, 1997 (Mw=4.7) took place in the Korean peninsula. The Heicheng earthquake of February 4, 1975 (M=7.4) and Tangshan earthquake of July 28, 1976 (M=7.20) followed the deep-focus earthquakes of September 29, 1973 (M=6.5) and June 29, 1975 (M=6.2) in the East Sea. Generally speaking the occurrence of large earthquakes is accompanied by a series of disastrous earthquakes (not aftershocks) in the regime of neighborhood in Asia according to the seismological community in China and Japan. For example, the northern Sumatra earthquake of December 26, 2004 (M=9.1) and Sichuan Great Earthquake of May 12, 2008 (M=8.0), the Tohoku Great Earthquake of March 11, 2011 (M=9.0) are related to each other with a longer inter-
val whereas the Sichuan earthquake of April 20, 2013 (Mw=6.6), Kuril earthquake of April 19, 2013 (M=7.3), SE off Japan earthquake of April, 21, 2013 (M=6.1), and SW Yellow Sea earthquake of April 21, 2013 (M=4.9) are relevant to each other with a shorter interval. So we cannot rule out that most of large earthquakes around the Korean peninsula and the Far East are related to each other because the interplate earthquakes between the plate boundaries influence the other boundaries resulting in occurrence earthquakes not only within the boundary (intraplate earthquakes) but also along the plate boundaries (interplate earthquakes). Therefore the present earthquake resistant design for nuclear power plants in the southeastern part of the Korean peninsula is unmet to prevent the earthquake disaster in the future. Therefore we need to update the design of the safety in nuclear power plants of Korea with the most up-to-date methods and data.

7. Conclusion

The present earthquake resistant design for nuclear power plants is not sure in the light of findings of active faults and recent earthquakes as well as the state of saturation of radioactive waste disposal facilities including the accumulated saturate spent fuel and a cluster of nuclear power plants in the southeastern part of Korea. We need reassessment of seismic design for nuclear power plants and radioactive waste disposal facilities in the nuclear power plant site in the southeastern Korean peninsula based on recent seismological technology and updated more data. Especially we have to find out how to control the nuclear spent fuel storage which would be over-saturated by the forthcoming 2020. Furthermore it has been found that some parts of the reactors had been delivered in the nuclear power plants of Kori and Wolsung with wrong mal-functioned ones nowadays. For the same reasons go another reactor in Kori after its maintenance is not back on the grid, while a new reactor in Wolsung will not even put into operation once in a while. Despite the scandal surrounding the fake security certificates of nuclear parts and the growing public unease as well as the Fukushima Nuclear Disaster, the government remains committed to nuclear power for energy supply of industrial locations in South Korea. Therefore we need higher level of seismic re-evaluation for all Korean nuclear power plants because of unsecured parts used in nuclear power plants and the over-saturation of the nuclear spent fuel storage.

References