MOST IMPORTANT ACTIONS OF NUCLEAR POWER PLANT AT EARTHQUAKE ARE "STOPPING","COOLING","CONFINING RADIOACTIVE MATERIALS"

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ABSTRACT :

On July 16th2007, Niigataken Chuetsu Oki earthquake with M6.8, h=17km, hit directly Kashiwazaki Kariwa nuclear power plant (8.2GW) of Tokyo Electric Power Co.. A transformer outside of a plant building had a fire due to the leakage of insulation oil caused by the ground subsidence. The water containing extremely little radioactive material overflowed the storage pool for the used nuclear fuel by the sloshing and it went out to the sea. These are not serious accidents as a result. In spite of these accidents, the nuclear power plant succeeded to do "Emergency stop", "Cooling from 280℃ to 100℃", and "Confining in the radioactive materials". Although the nuclear power plant was hit by the strong earthquake ground motion the maximum acceleration of which amounts to 680gals on the underground bedrock, three actions, "Stop", "Cooling", and "Confining" were successfully carried out. The reason of success might be that the most important facilities have the earthquake resistance 3 times of the general RC buildings in Japan and sufficient ductility.

KEYWORDS: Nuclear power plant, earthquake, earthquake resistant design, safety allowance

1. THE MOST IMPORTANT ACTIONS FOR A NUCLEAR POWER PLANT AT EARTHQUAKE

The most important things that a nuclear power plant has to do when the strong earthquake attack, is that it does not discharge the large amount of radioactive materials outside. Therefore, main purpose of earthquake resistant actions of the nuclear power plant, is to execute completely "to stop", "to cool", and "to confine" even if it is suffered severe damage by the strong earthquake.

2. A STRONG EARTHQUAKE HIT THE LARGEST NUCLEAR POWER PLANT OF JAPAN

On July 16th2007, Niigataken Chuetsu Oki earthquake with M6.8, h=17km, in direct distance 23km, hit Kashiwazaki Kariwa nuclear power plant (8.2GW) of Tokyo Electric Power Co., the one of the biggest nuclear power plant of Japan.

2.1. Earthquake Emergency System

The plant has the following emergency stopping system. When the seismometers at the plant basement observe more than 120gals, the control rod automatically get insert into the nuclear fuel bars in order to stop the reaction of the reactor.

2.2. Max. Acc. 680gals was Observed at the Basement

Although acceleration of the quake recorded on the basement of the plant were from 322~680gals, the input acceleration for the earthquake resistant design at the same place was 273gals. Observed acceleration was approximately 2.5 times of the input for the design, however, there was no damage on the important facilities for the emergency measures.

2.3. Many Accidents Occurred in the Plant

Those damage were divided into the following groups;
1. Fire of a transformer.

Figure 1 Fire of a transformer
by courtesy of 9th Regional Headquarters of Japan Coast Guard

Figure 2 After the fire of the transformer
You can see the fire convention wall behind the transformer, change to dark color by smoking.
by courtesy of Tokyo Electric Power Co. (TEPCO)

2. Leakage of a little amount of water containing a little radioactive materials, by sloshing of the water pool keeping the used nuclear fuel bars, to outside sea.
3. Release of air containing extremely little radioactivity through a exhaust tower.
4. A control rod could not be pulled out from the nuclear fuel bars after the earthquake .
5. Damage on the axle of the overhead traveling crane was occurred.
6. Drop down of a blow out panel of a building.

7. Subsidence of soft sand and ground.

Figure 3 Ground subsidence near the building
The building was supported on the bedrock.
by courtesy of TEPCO

Figure 4 Cracks on the underground RC wall of a C class building produced by earth pressure
by courtesy of TEPCO

8. Various damage on the C class group.

Figure 5 Falling down of various things inside of a C class building
by courtesy of TEPCO

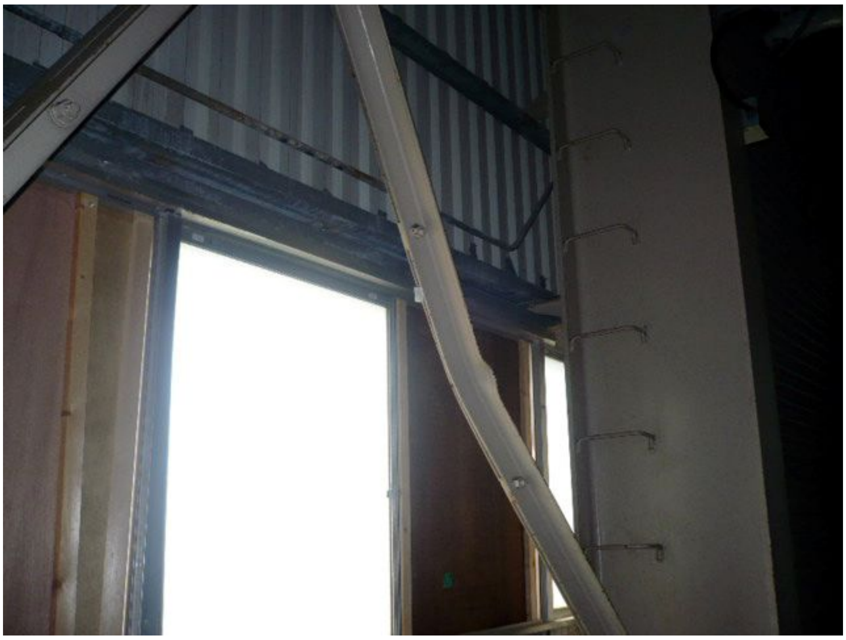

Figure 6 Buckling of a steel bracing in a C class building
by courtesy of TEPCO

Figure 7 Damage of bolts in a C class building
by courtesy of TEPCO

9. No damage on A class building.

Figure 8 RC wall 1.5m thick of an A class Reactor building
The thickness was decided by the earthquake force 0.48G, 3 times of C class building.
by courtesy of TEPCO

Figure 9 Reinforcing steel bars 51mm of diameter in the RC wall
A lot of steel bars give the facilities a lot of "ductility".
by courtesy of TEPCO

3. ACTUAL EMERGENCY PROCESS TAKEN AFTER THE EARTHQUAKE

1) No.3, 4, and 7 reactors were under ordinary operation and No.2 under starting operation, at the time of earthquake, and control rod was normally inserted and the reactor was automatically stopped.
2) The cooling process of the reactor was normally operated and all the reactors were safely lowered to 100℃ from 280℃. It took the longest time, 20 hours and 41 minutes for the No.4 reactor.
3) The fire was generated by a transformer. There was no fear of fire spread, because it was separated from the B class RC building and has a fire prevention RC wall backwards.
4) The joint of the driving shaft of overhead traveling crane in No.6 reactor building was broken, however, this accident did not cause the falling of the crane itself.

The reason why the emergency measures such as "Stopping the reactor" have been done properly in spite of so many accidents previously mentioned occurred in the plant, might be that the occurred accidents have nothing to do with the important emergency measures. The facilities for the emergency measures are designed to resist the earthquake force three times larger than the usual, therefore, they had no damage in the measures.

4. EARTHQUAKE RESISTANT DESIGN OF NUCLEAR POWER PLANT

Fist of all, the facilities of a nuclear power plant are classified into the following three groups.
1) Class A group such as "Nuclear reactor, Cooling system, etc., and its building" have the direct and important role for the action "Stopping", "Cooling", and "Confining radioactive materials". The design seismic coefficient for Class A group is taken three times of the usual buildings in Japan Building Code.
2) Class B group such as " Turbine and so on, and its building" have a little relationship with the above mentioned three emergency actions. The design seismic coefficient for B group is taken 1.5 times of the usual buildings in Japan Building Code.
3) Class C group such as the generator, transformers, etc., has no direct role on the previous three emergency actions. The design seismic coefficient for C group is equal to the general buildings in Japan Building Code. It means that the C class facilities might be suffered damage, when the usual buildings outside of the plant have

the damage at the time of earthquake.
4) The important buildings such as Class A or B should be supported on bedrock.

At present, we found no damage in Class A facilities, and one in the Class B group, that is, a damage on the driving shaft joint of a traveling crane, and many, for example, the fire of the transformer, etc. in Class C group. It is natural that many damage occurred in the Class C facilities in the plant, because the Class C facilities in the plant and the general buildings outside were made earthquake resistant design based on the same earthquake force. Therefore, if the building outside suffer several damage, the Class C facilities would suffer damage in the same degree.

5. SUFFICIENT SAFETY ALLOWANCE (DUCTILITY)

Why did not the facilities in the plant have the damage due to 680gals ground motion ? I can point out the following reason. The facilities are designed so that the stress remains within the elastic range due to $3\times C_I$(=0.48G) earthquake force. Even if the strain comes beyond the elastic range, it must remain within 2000 micro. The safety allowance of the strain is approximately 20 times of the elastic limit. This is a large amount of safety allowance. Therefore, even the C Class facilities designed for $1\times C_I$(=0.16G) earthquake force, did not suffer severe damage, owing to the sufficient safety allowance(ductility).
The ductility of RC structures comes from the amount of steel bars used.

6. THE BEHAVIORS OF SOIL AGAINST EARTHQUAKE

Many damage occurred in Kashiwazaki Kariwa nuclear power plant are caused originally from the settle down of the backfilling soil. The buildings supported by the rock, did not suffer any damage by earthquake shaking, however, the cause of the fire of the transformer was the subsidence of the soil. Generally speaking, soft soil or ground is very weak against the earthquake. As a result, many damage occur in the facilities constructed on the soft soil or ground. A or B Class structures were constructed on the rock., therefore, they had almost no damage.

7. CONCLUSIONS

Kashiwazaki Kariwa nuclear power plant of Tokyo Electric Power Co. was hit by the strong earthquake with M6.8 in distance of 23km. The seismometer at the plant basement observed the 680gals in max. acceleration which is approximately 2.5 times stronger than the input earthquake force for the design seismic coefficient of earthquake resistant design. However, the damage was not serious and the most important three actions of the nuclear power plant, that is, “Stopping”, “Cooling”, “Confining the radioactive materials” were done automatically and completely, immediately after the seismometers observed the acceleration over 120gals. The reason why the plant could stop safely, in spite of the severe shaking, might be that (1) the facilities to do the emergency three actions: “Stopping” etc. have been constructed based on seismic force of 3 times, (0.48G) of the usual building, and (2) they are supported on the hard bedrock, and (3) a lot of steel bars in concrete give a lot of ductility (safety allowance).