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DAMAGE ON HAZARDOUS MATERIALS FACILITIES

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ABSTRACT: The 2011 off the Pacific coast of Tohoku Earthquake caused damage to oil storage tanks and other hazardous materials facilities in petrochemical industrial complex. The damage of the oil storage tanks and hazmat facilities has a different aspect by area. For example, the oil storage tanks and other hazmat facilities damaged mainly by the Tsunami on the pacific coast and the strong ground motion caused the fire in LPG tank area. According to the investigation by the FDMA, 3,324 facilities damaged due to the earthquake. This is 1.6% of the total Hazmat facilities (211,877) in the east Japan area.

Key Words: Oil storage tank, Hazmat facilities, sloshing, Fire, Leakage, Long period strong ground motion

INTRODUCTION

The 2011 off the Pacific coast of Tohoku Earthquake (Mw9.0) occurred on March 11, 2011 and shook Miyagi Prefecture with a strong earthquake of magnitude 7 (Japanese scale) . A vast range over an east part of Japan suffered damage by a strong ground motion, moreover wide range of the pacific coast of Tohoku area suffered damage by Tsunami. The earthquake caused damage to oil storage tanks and other hazardous materials facilities in petrochemical industrial complex. For example, some of them caught fire after the earthquake and large amount of oil leaked from oil storage tanks. Therefore, National Research Institute of Fire and Disaster have investigated damage including the fires and failures of the oil storage tanks and other hazmat facilities.

No one shall not install oil storage tank for gasoline or crude oil without permission by the local fire authority in Japan. Oil storage tanks must be built strong enough according with the technical standard of the Fire Service Law in order to avoid fire and leakage. According to the article 11 of the government ordinance about the regulation of the hazardous materials, oil storage tanks shall have enough strength to withstand the earthquake and their foundations and soils shall be strong enough.

However, many hazardous materials facilities and petrochemical complexes suffered damage by the earthquake and the tsunami, such as fire and leakage.

OUTLINE OF THE DAMAGE OF HAZMAT FACILITIES

According to the investigation by the Fire and Disaster Management Agency, facilities damaged by the earthquake amount to 3,324, this is 1.6% of the total hazardous materials facilities (211,877) in the east Japan area. 1,404 hazmat facilities were damaged by the strong ground motion, on the other hand

1,807 hazmat facilities were damaged by the Tsunami and the rest 113 remain unsolved. Among the damage, fires occurred in 42 facilities, oil leakage occurred in 122 facilities.

AREAS FOR ON-SITE INVESTIGATION

Hazardous materials facilities over the wide area in eastern Japan suffered damage in the earthquake. National Research Institute of Fire and Disaster have investigated the 10 areas, such as Kesennuma city, Sendai area (Sendai city, Tagajo city, Shichigahama town), Iwaki city, Kashima area (Kashima city, Kamisu city), Sakata city, Shibata city, Niigata city, Ichihara city, Kawasaki city and Kuji city. Among these areas, fire occurred in Sendai area and Ichihara city.

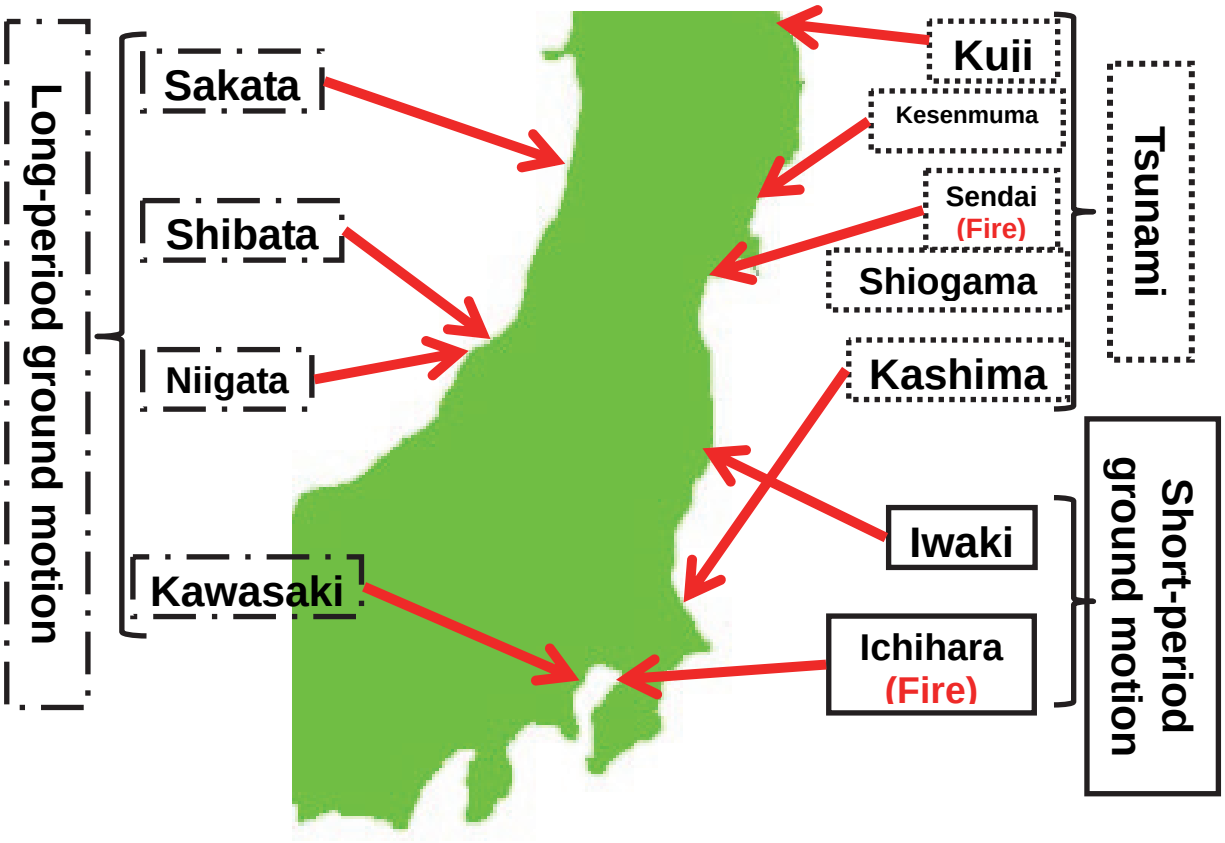

Fig. 1 Type of damage observed mainly in Petrochemical Complex

CHARACTERISTIC OF DAMAGE BY AREA

The investigations were carried out from the viewpoints of that the damage of the oil storage tanks (e.g. failure in shell plates, bottom plates and floating roofs) is severe to alter the technical standard of the Fire Service Law, what is the cause of the fire which occurred in the Sendai area and in the Ichihara area, what kind of damage did the hazmat facilities suffered in the Tsunami incursion areas.

Typical damage of the hazmat facilities in each area

The damage of the oil storage tanks and hazmat facilities has a different aspect by area. In this section, the area for on-site investigation is separated into three areas as ‘along the Pacific coast’, ‘along the Sea of Japan’ and ‘along the Tokyo bay’. Typical damage of the hazmat facilities in each area are

described below.

Along the Pacific Coast
(a)Many tanks and pipelines floated and displaced by the buoyancy and the force of the Tsunami.
(b)Foundations of the tanks were swept away by the Tsunami.
(c)No severe damage of the floating roofs by the liquid sloshing.
(d)Few damage on storage tanks by the earthquake.
(e)Liquefaction by the short period strong ground motion.

Along the Sea of Japan
Fractures of the pontoons due to the liquid sloshing and oil spill onto the deck of the floating roofs.

Along the Tokyo Bay
Sinking of the floating roof and other damage by the liquid sloshing

INVESTIGATION RESULTS

The outlines of the damage of the hazmat facilities are shown below.

Oil leakage in Sendai area

Photo 1 shows the heavy oil spill in the dyke. The tank indicated as #1 in photo 1 is empty when the tsunami struck and submerged into the sea water up to 3.5m high from the bottom plate. The tank did not uplift nor displace even though it was empty. Many pipelines have been bent at the #2 in photo 1 and the large amount of oil leaked from the pipelines spilled all over the dyke and the road beside. These pipelines presumably washed away by the tsunami. The largest fracture was found at an elbow in one of the heavy oil pipeline. Its length is approximately 10cm and its width is approximately 3cm.

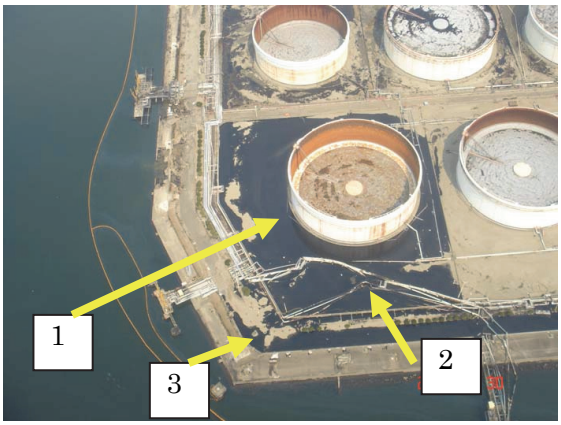

Photo 1 Heavy oil spilled in the dyke

Oil storage tanks washed away by the Tsunami

In Kesennuma city, 22 out of 23 above ground oil storage tanks were washed away by the Tsunami. The local fire authority announced that the total amount of oil flowed out of the oil storage tanks were assumed to be 11,721 kL and type of oil is heavy oil, kerosene, diesel fuel and gasoline. Photo 2 shows an oil storage tank which was drifted and collapsed by the Tsunami. It is reported that the large fires

occurred in Kesennuma city. However, no oil storage tank found to be burnt except the one found in Oshima area.

Photo 2 Oil storage tank drifted and collapsed by the Tsunami

In Kashima area, a sea bank and a berth were damaged by the Tsunami. The berth shown in photo 3 was struck by a drifted oil tanker and collapsed.

Photo 3 Berth collapsed by an oil tanker strike

Fires at petrochemical complex

Fires occurred at a refinery in a petrochemical complex in Sendai area. Photo 4 shows a section of the refinery that was burnt out completely by the fires. There were gasoline tank, asphalt tanks, molten sulfur tanks and shipping yard in the burned-out section. Photo 5 shows a burned-out gasoline tank. It seems that the tank inclined to the Pacific Ocean after the Tsunami strike and it collapsed due to the fire. The soil of the dyke and the foundation were washed away by the Tsunami. The welded part of the gasoline tank between the shell plate and the bottom plate fractured along approximately 2.4m.

Photo 4 Burned-out section in a refinery

Photo 5 Burned-out gasoline tank

Explosions of LPG tanks

In Ichihara city which locate on the eastern shore along the Tokyo bay, there were fires in which many LPG tanks exploded. It took ten days after ignition to extinguish fires. The largest fire ball in the fire is shown in photo 7. Its diameter is about 600m judging from the height of the plant extractor stack pipe. Many fragments of the LPG tanks scattered in the explosions, therefore the fire spread to the asphalt tanks, the control room and the neighboring factory.

Photo 6 All legs of the LPG tank collapsed and buckled by the earthquake

Photo 7 Largest fire ball in the fire with approximate 600m diameter

Damage by liquefaction in petrochemical complex

In Iwaki city along the Pacific coast, there was damage due to liquefaction caused by short period strong ground motion. Photo 8 shows an example of a settlement of oil storage tank. The valve of the tank slightly contact to the ground, therefore the asphalt of the berm was removed in order to avoid the failure of the neck of the nozzle in the future settlement.

In Kashima area, the wall of the dyke settled and inclined because of liquefaction. As shown in photo 9, fractures of joints of the dykes were found in some walls. Some of them have rubber sheets protection in order to maintain its function in case of joint fracture. Some rubber sheets tore and lost its function of retaining oil inside the dyke.

Photo 8 Tank settled because of liquefaction around the foundation

Photo 9 Fracture of wall joint of the dyke with rubber sheet protection

Damage of oil storage tanks by liquid sloshing

Typical damage of oil storage tank caused by liquid sloshing was found mainly along the Sea of Japan and the Tokyo bay. Oil spilled onto the deck of the floating roof in Niigata city, Shibata city and Kawasaki city. Oil marks on the surface of the shell plates were found in many oil storage tanks. Photo 10 shows crude oil leaked from the fracture part of pontoon of floating roof. In Kawasaki city, floating roof of heavy oil tank completely sank three days after the earthquake as shown in photo 11.

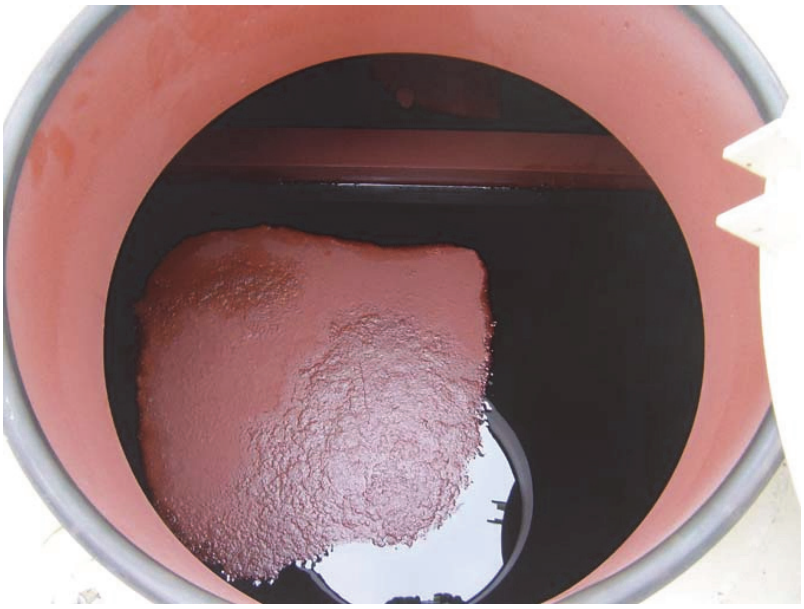

Photo 10 Crude oil leaked from the fracture part of pontoon of floating roof

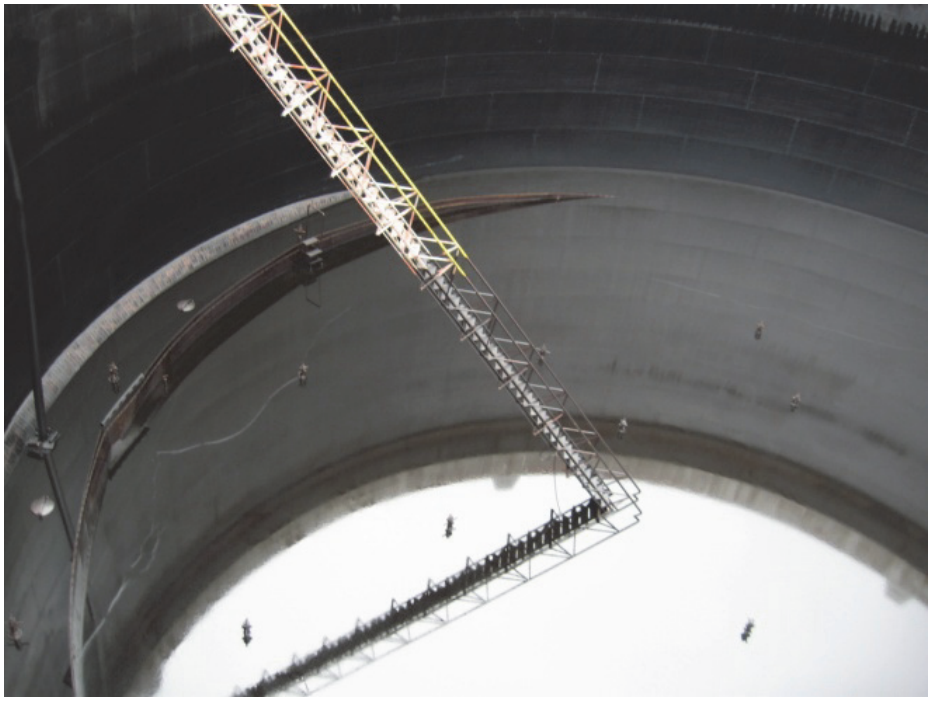

Photo 11 Sinking of floating roof

In Sakata city which locate along the Sea of Japan, the aluminum inner floating roof of gasoline tank was broken completely. Photo 12 shows one of broken float tubes of the inner floating roof. Its length is about 6.7m and its diameter is 25.4cm. The natural period of the first-order mode of the sloshing is 4.19s for the tank and velocity response is about 200cm/s at the period. The maximum sloshing height is calculated as 202cm by applying the two dimensional response analysis method (Zama, 1985) and the inclination angle of the inner floating roof is calculated as 15 degree simultaneously. Deck skin and clump beams were also broken up, though the photos are not presented here.

Photo 12 Broken float tube

Other failure

In Kuji city, there are underground rock cavern oil tanks. The tanks suffered no damage by the Tsunami, because the door of the tunnel shown in photo 13 was properly closed by the employee. However, the aboveground facilities were completely destroyed by the Tsunami as shown in photo 14.

Photo 13 Door of the underground rock cavern oil tanks

Photo 14 The tank of which the shell plate buckled and the heat reserving materials tore off

CONCLUSIONS

It seems that there is few damage of the tank body by the ground motion of the earthquake. Many pipelines were damaged by the Tsunami, since the emergency shutdown valves did not work because of the blackout after the earthquake. Therefore, large amount of oil spilled out to the dyke. Many fractures were found in the floating roofs. The floating roofs which meet the technical standard of the earthquake proofness did not suffer damage in the earthquake.

Many small tanks were swept away by the Tsunami. The bottom plates of the tanks were broken. However, some empty tanks did not swept away by the Tsunami. The Tsunami washed away the soil of the foundations of the tanks and the soil inside the dykes. The damage of the hazmat facilities was severe and the damaged hazmat facilities located in huge area of the eastern Japan. The cause of the damage of the hazmat facilities is still unclear in some parts. Therefore, further investigations and detailed analysis is need in order to elucidate the mechanism of the damage.

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