Damage of Oil Storage Tanks due to the 2003 Tokachi-oki Earthquake

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The 2003 Tokachi-oki earthquake (M=8.0) occurred on 26 September, east off Hokkaido, north of Japan, and caused two disappeared by tsunami and more than one hundred collapsed houses. Considering its magnitude, the extent of damage is not so large. On the other hand, oil storage tanks in and around Tomakomai, a coastal city in southern Hokkaido, were severely damaged by liquid sloshing. Especially in the Idmitsu Refinery, two fires broke out and six floating roofs sank, and 30 tanks suffered some amount of damage such as overflow and splash of oil, deformation of rolling ladder, weather shield, guide pole, gauge pole and air foam dam and so on. Here, we present the damage oil storage tanks and sloshing behavior during the earthquake.

Many acceleration records were obtained in the earthquake. At Tomakomai, epicentral distance is about 225km, PGV is 31.03 cm/s and duration becomes longer, and long-period components are dominant, which are considered as an effect of thick sediment of the Yufutsu plain.

As mentioned above, damage of oil storage tanks at Tomakomai was caused by liquid sloshing, which was excited by the long-period ground motion. Japan fire service law regulates the maximum sloshing wave height, which is calculated assuming the velocity response spectrum at a period of sloshing as 100 cm/s. The response spectrum of record at Tomakomai, however, exceeds about two times as the regulation at periods from about 4 to 8 sec. Thus, it is considered that most of the oil tanks suffered damage. This situation is very similar to that of TUPRAS refinery during the 1999 Kocaeli, Turkey earthquake. The severe damage of oil storage tanks was caused by large liquid sloshing due to the unexpected ground motions at long-period range.

Maximum sloshing wave height (Wh) is calculated by the equation (1).

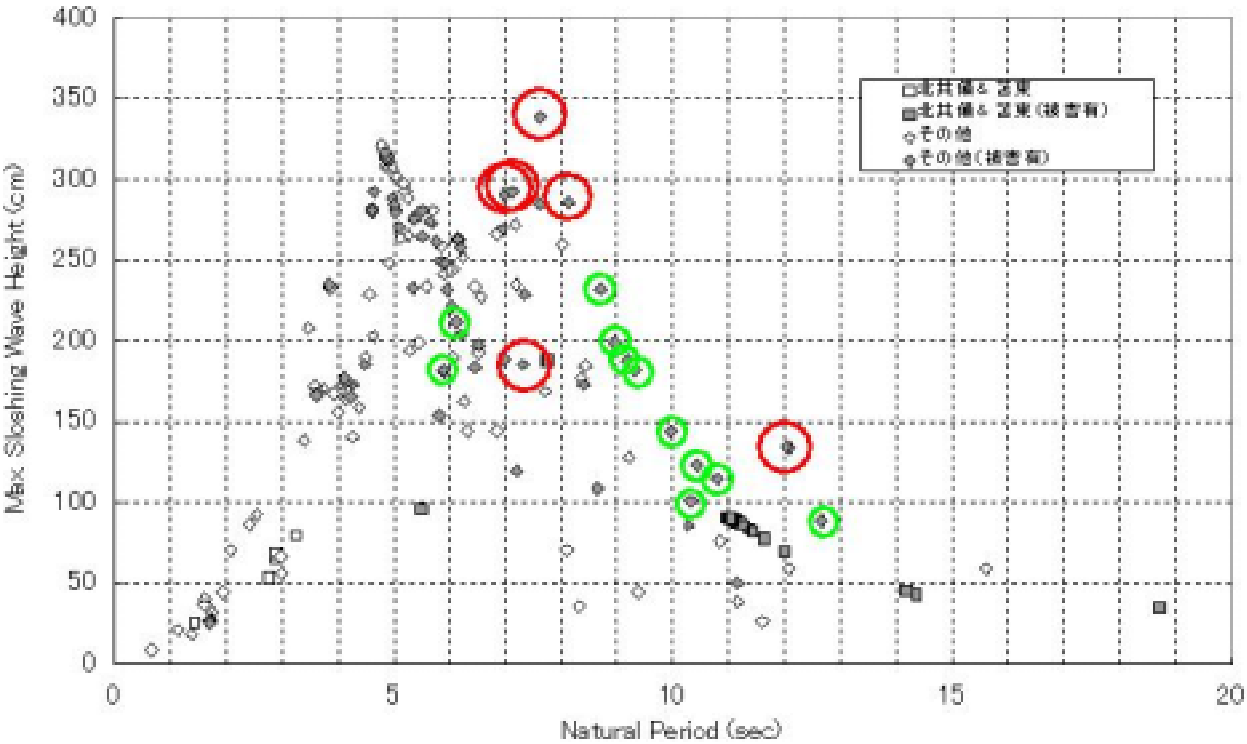
Wh = D /2g*0.837(2 PI/Ts)*Sv (1)

where, D, g, Ts, and Sv are diameter of a tank, gravity acceleration, sloshing period, and velocity response spectrum, respectively. Ts is given as follows when liquid level is given as Hl.

Ts = 2PI D**0.5/(3.682g)*coth(3.682Hl/D) (2)

Since observed sloshing wave height data were not so much, we estimated Wh for all tanks as shown in the figure, after checking the agreement between calculated and observed Wh using seismograms at Tomakomai. Estimated Wh exceeds 3 m at periods 5 and 7.5 sec, and exceeds 2m from 3.5 to 9 sec of sloshing period. Very severe damaged tanks were in general corresponding to the highest Wh at each sloshing period.

In consideration of sever damage of oil storage tanks in Tomakomai due to the 2003 Tokchi-oki earthquake, Fire and Disaster Management Agency will make policy to revise Sv in equation (1) based on the prediction results by the empirical prediction results. The fact that floating roofs sank is very serious, because such situation will lead to full-surface tank fire with high possibility. Furthermore, the Headquarters for Earthquake Research Promotion pointed out that large earthquake like the Tokachi-oki earthquake will occur in the near future. Therefore, it is very important and urgent to enforce the strength of floating roof. For that purpose, it is needed to clarify where and how force was loaded by liquid sloshing by detail investigation of sinking roofs.



400
350
300
250
200
150
100
50
0
Max Sloshing Wave Height (cm)
0
5
10
15
20
Natural Period (sec)
北共備& 苫東
北共備& 苫東(被害有)
その他
その他(被害有)