6 DAMAGE TO PORT FACILITIES

In the life cycle of port structures, devastation by an earthquake might be a rare event. However, once it occurs, the magnitude of the consequences will be so large that the effects of earthquakes can be a major issue of national interest. Earthquakes thus pose low probability-high consequence threats to port structures.

The consequences should be most devastating if a port happens to be located in the seismic source area. This was actually the case for Kobe, Japan, earthquake of 1995. The Kocaeli, Turkey, earthquake of August 17, 1999 is the most recent example.

The reconnaissance was carried out as a cooperative research from September 1 to 5, 1999 by JICA team and from to 10, 1999 by JSCE team. The objective of this reconnaissance was to obtain and compile data for evaluating seismic performance of port structures undergoing the near field earthquake motions. These data should be essential for evaluating ultimate response of port structures and valuable for developing a new design procedure based on performance concept. The reconnaissance on the ports located outside of the seismic source region was also carried out to obtain data for evaluating seismic performance of port structures in these areas relative to those in the seismic source region.

This is a preliminary report. It compiles earthquake, structural and geotechnical data, including preliminary discussions, but does not contain detailed analysis. Location of epicenter is shown in Figure .1 with the locations of several ports investigated.

6.1 Damage State at Port Facilities around Eastern Marmara Sea

6.1.1 Haydarpa   a Port

Haydarpa a Port is located in Istanbul, located 90 km northwest of the epicenter. The estimated peak ground accelerations were 0.05 to 0.1 g. Haydarpa   a Port receives about 2500 ships/year, loading/unloading about 1.5 million tons of containers and 4 million tons/year of general cargoes. Handling equipment of the port includes two container gantry cranes of 40 tons capacity. 21 shore and yard cranes of 3 to 35 tons capacity. The quay walls are cellular block type as shown in Figure 6.1, with water depths ranging from -6 to -12 m. Damage to quay walls are generally minor.

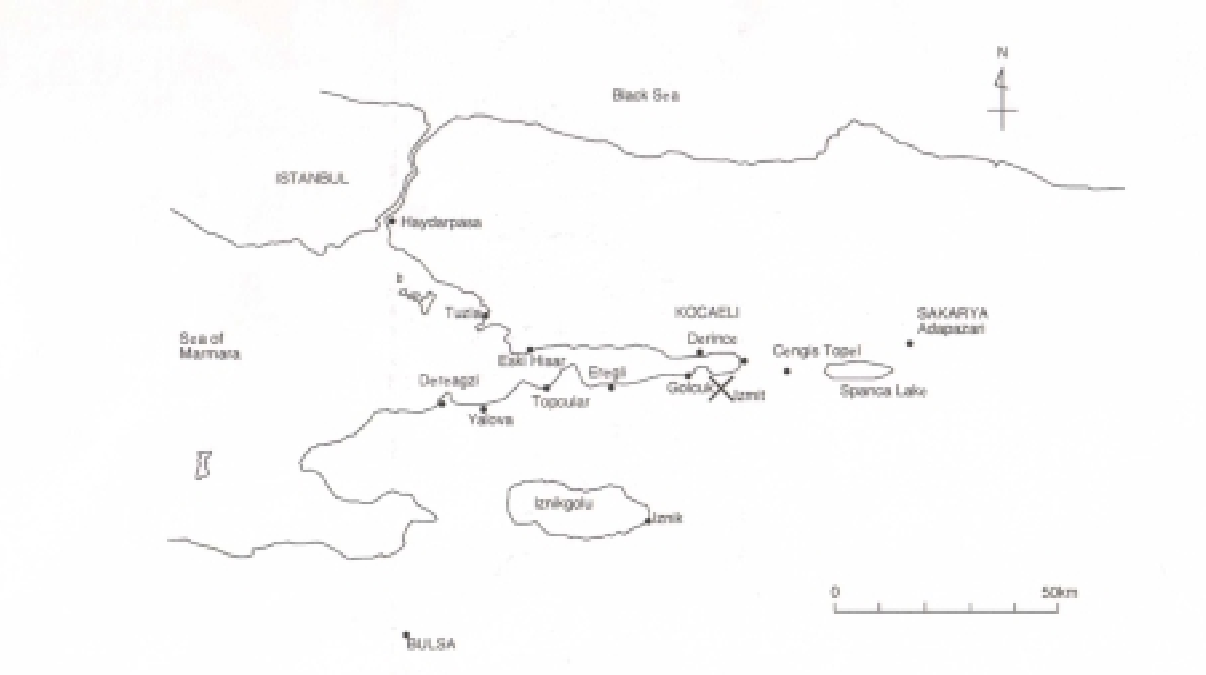


Figure 6.1 Epicenter and location of the surveyed ports

6.1.2 Tuzla PORT

Tuzla port is located around 60km west of the epicenter. The quay walls are cellular block type with water depths ranging from –5.5 and –10 m. Damage to quay walls are the horizontal movement of block 0.4m, backfill settled 0.1m.

6.1.3 Dar ca PORT

Dar ca port is ferry terminal port located in the south east of Tuzla port. From helicopter observation, some cracks on the apron were detected. However, ferry boats are on duty.

6.1.4 Derince Port

Derince Port is located near Izmit, where the peak ground accelerations were approximately 0.25 to 0.3 g. Derince Port receives about 600 ships/year, loading/unloading about two million tons/year of general cargoes. The plan of the port is shown in Figure6.2. Containers are handled by general purpose fixed shore crane of 35 tons capacity. Berth No. 6 is used for ro-ro operations. The quay walls are cellular block type as shown in Figure 6.3, with water depths ranging from –7m to -15 m. Foundation soil is a stiff clay which range of STP-N value from 30 to 60. Backfill behind the walls are hydraulic fill of fine grained sandy soil.

Damage to quay walls were found at No.6 General Cargo Quay (-12m, 220m), No.7 Quay (-10m, 160m), and No.8 Quay(-6m, 120m). Concrete cellular block walls did not collapse but moved toward the sea 0.7m maximum. Large settlement (roughly 0.5m) the backfill occurred. Boiled fine sands were find around the warehouse located behind the No.7 Quay.

There was not significant damage to quay walls at Nos. 2 through 4 Quays (-7m, 82m; -15m, 400m) , the steel pile supported wharf with batter piles as shown in Figure6.4. The general purpose crane on No.7 Quay which capacity is 5t, was overturned(Figure 6.5) due to the settlement of land side rail as 0.5m and earthquake motion. Other cranes were not overturned, however, suffered yielding of legs.

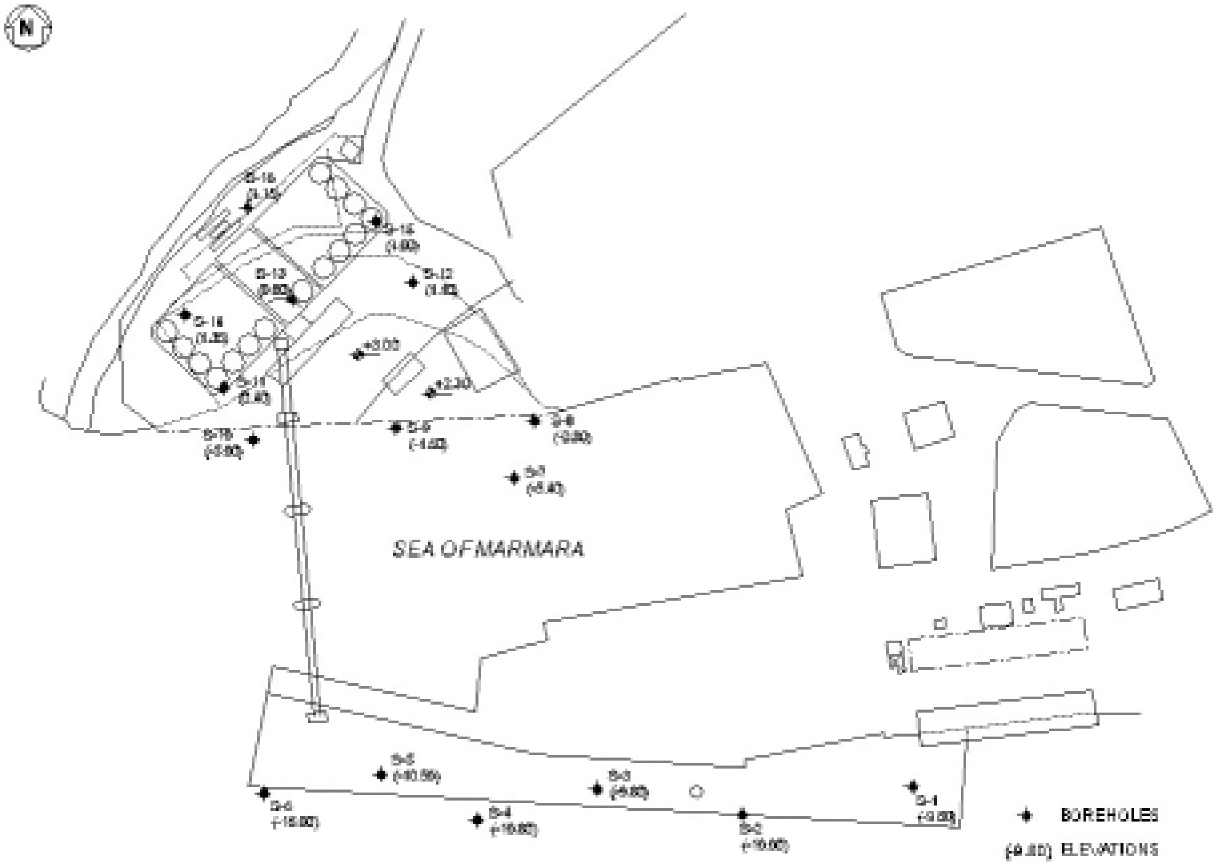


Figure 6.2 Plan of Derince port

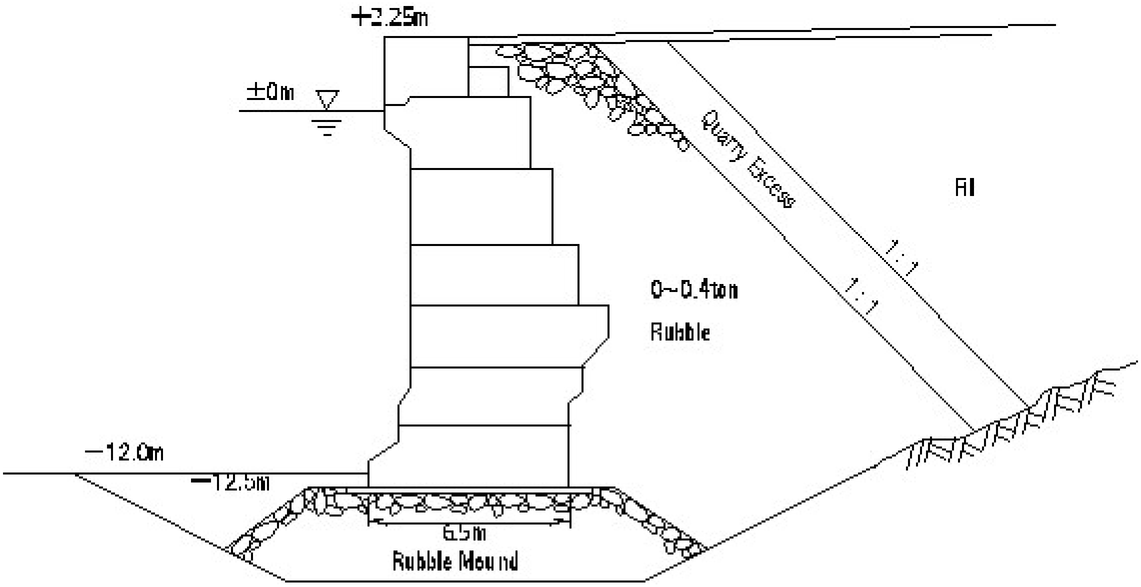


Figure 6.3 Cross section of quay wall at Derince port

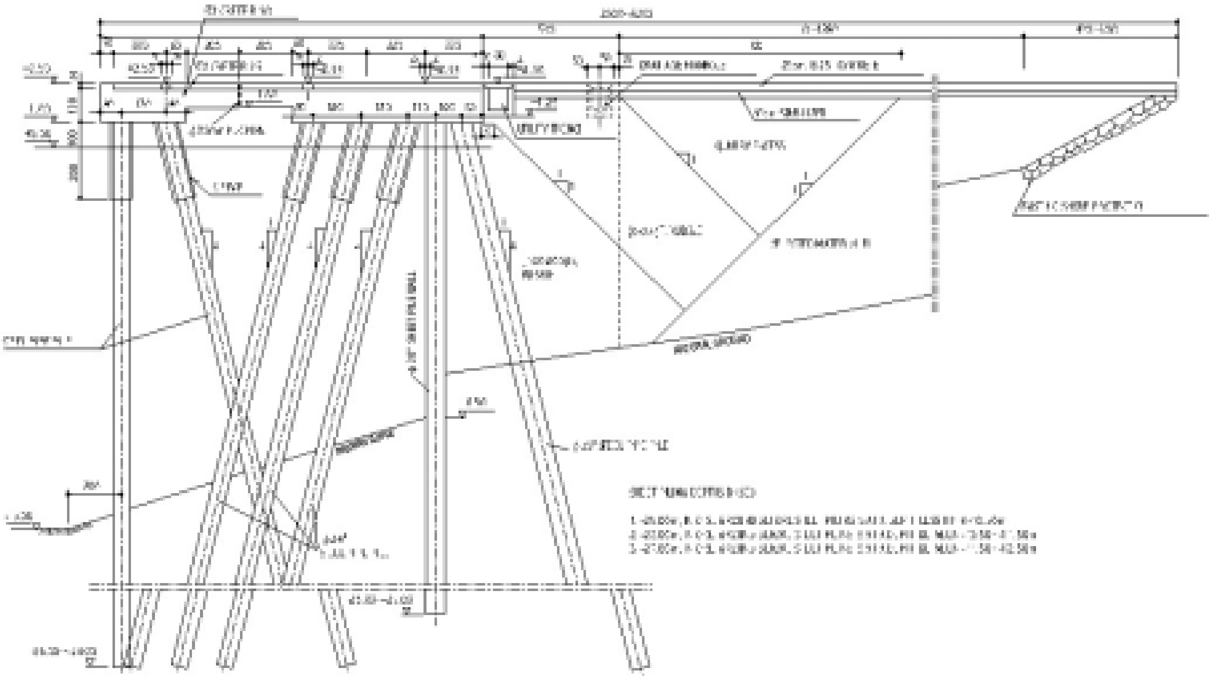


Figure 6.4 Cross section of the open type wharf with batter piles.

Figure 6.5 Overturned crane

A grain silo of 95,000 tons capacity(Figure 6.6) supported by pile foundation were stable during the earthquake. The conveyer system between the silo and No.2 Quay had some damages due to the settlement of apron.

Figure 6.6 Grain silo

6.1.5 Yalova Port

Yalova port is located at opposite side of Istanbul. The rock fill type breakwaters were settled around 0.2m.

6.1.6 Port Facilities at PETKIM

Most of big factories such as chemical plant, have port facilities for load/unload chemical products. One of the most important function of the jetty is fire hazard prevention between ship and storage tanks during loading/unloading the products. Figure 6.7 shows the RC pile supported type dolphin (jetty) located near the Derince port. The upper top portion of pile show shear failure or corrosion. Generally speaking, the management of the factory is focused on the product section, however, it is strongly recommended that the inspection of residual strength of port facilities after the earthquake by port facilities design/construction specialists is needed.

Figure 6.7 RC pile supported dolphine

6.2 Discussions

The major damage of port facilities during the Kocaeli earthquake is concrete cellular block type quay wall(Figure 6.8 and 9) moved toward the sea due to the liquefaction of backfill.
To investigate the performance of the cellular block type quay wall, we conducted underwater shake table test as shown in Figure 6.10. The blocks stacked vertical (right hand side) is modeled as Yokohama Shinko No.5 quay (Uwabe, 1986). At the No.7 quay wall of Derince port, blocks are stacked with around 16 degrees slant. The backfill ground was constructed as a loose fine sand layer. The input motion was used YPT records with 3 axes. The test results(Figure 6.11a and b) show that the horizontal displacements of No.7 quay wall are smaller than those of the blocks vertical stacked quay wall. The underwater shake table test result expressing the constaint effect of the blocks with 16 degree slant stacking.

Several tests results from underwater shake table tests(Sugano et al.1996) , dynamic response analyses with effective stress concept of soils named FLIP(Iai etal. 1993) developed by Port and Harbour Research Institute results and lessons from the 1995 Hyogoken Nanbu

Earthquake, improvement of backfill soil is effective way to increase the earthquake resistance of quay walls during earthquake.

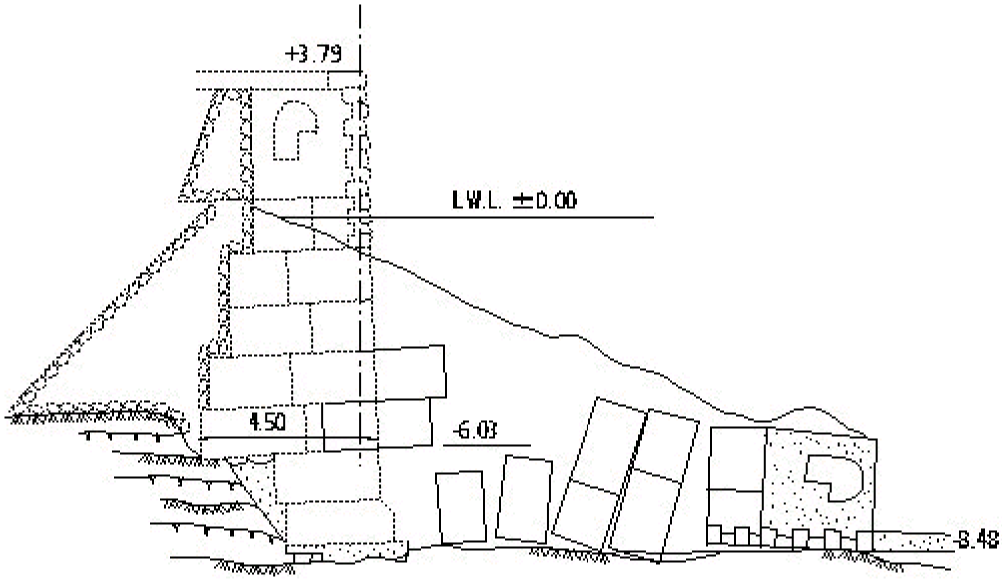


Figure 6.8 Cross section of quay wall at Derince port

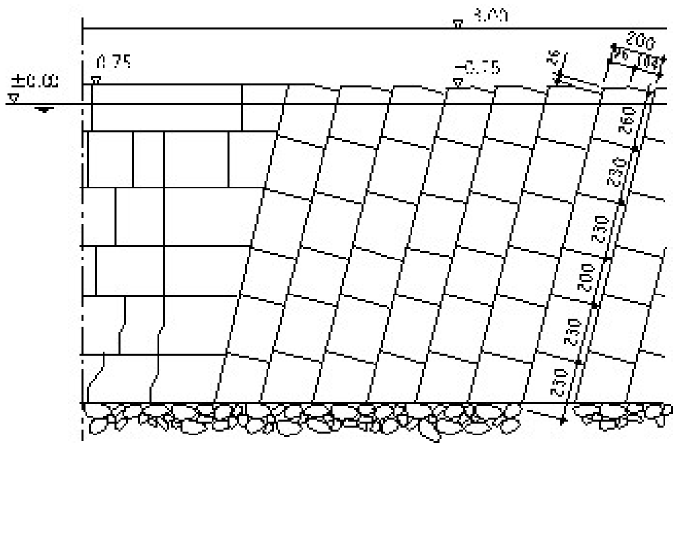
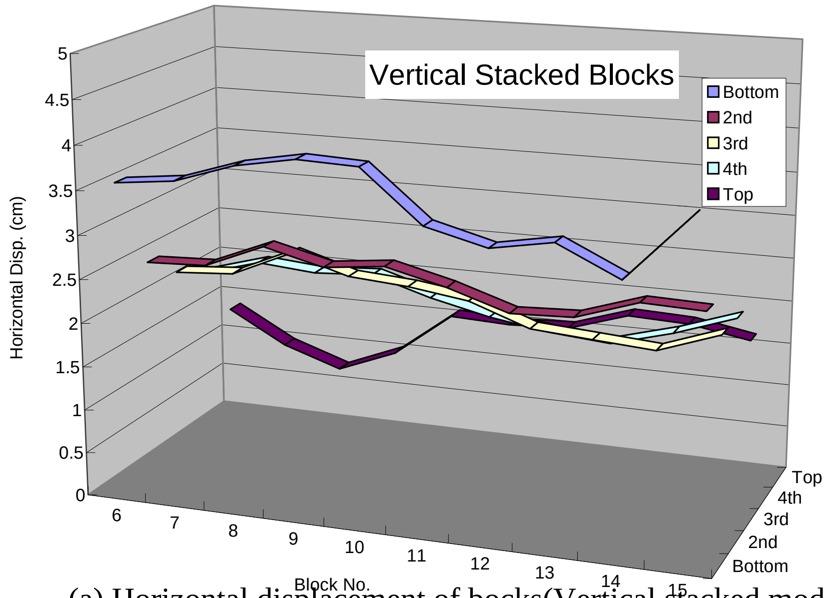


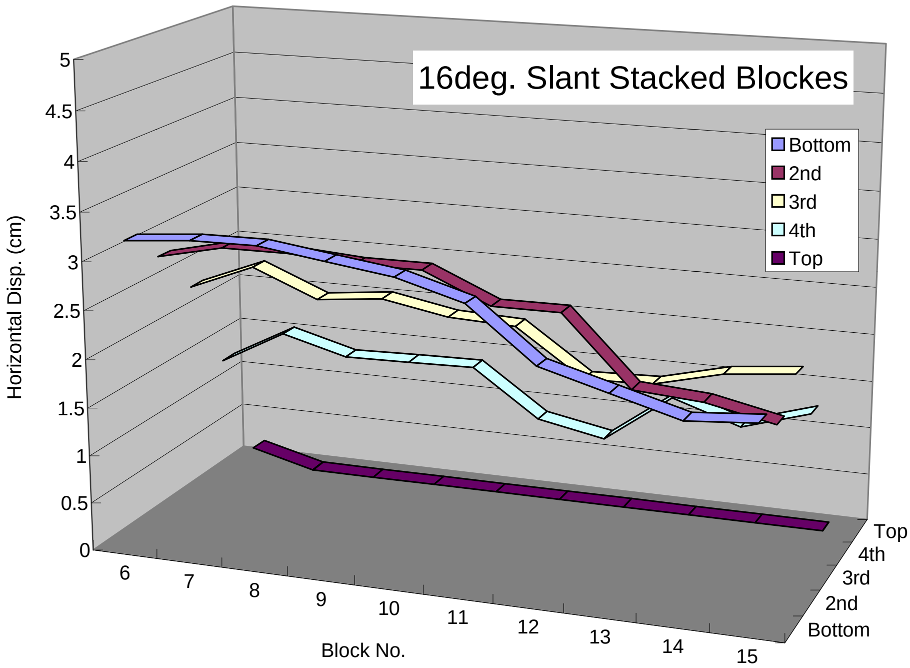
Figure 6.9 Concrete cellular block stack design

Figure 6.10 Underwater shake table test models

The functions of port facilities are mooring the ship, unload/load freights and transport the freights to/from land side, it is important to consider the seismic performances of whole port facilities during earthquake. To investigate the performance of general purpose crane located on the No.7 quay wall which was fall down, simple analyses(Yamamoto et al.1999) ware conducted. The prototype crane was reduced in the mass-spring model as shown in Figure 6.12 .We assumed the crane weight of 100t, height of gravitational center is 7m, natural frequency of 2Hz and damping is 0.025 from the rough estimation by Japanese cranes. The rail span was measured as 5.5m. The input motion is chosen NS component of YPT record with maximum acceleration of 313.85 Gal. The response time histories of acceleration and displacement are shown in Figure 6.13 a and b. The next cane (7.5 m rail span, 7t capacity, weight of 150t, height of gravitational center is 9m) was not overturned during the earthquake. Simple static analyses were conducted to calculate the condition of overturning occurrence. The origin of coordinate is set at the land side leg, then calculate the sum of momentum as listed in below with condition of 0.5 m land side leg settled, and finally we can obtain the overturning threshold level of pseudo static acceleration A in horizontal direction as shown in Figure 6.14.



(a) Horizontal displacement of bocks(Vertical stacked model)



(b) Horizontal displacement of blocks(16 deg. Slant stacked model)

Figure 6.11 Shake table test result of cellular block type quay wall

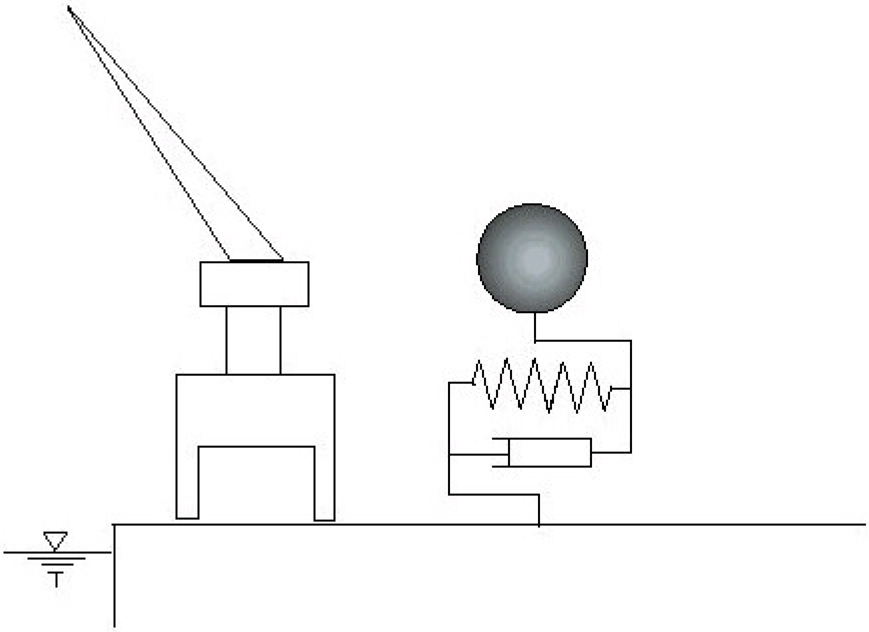
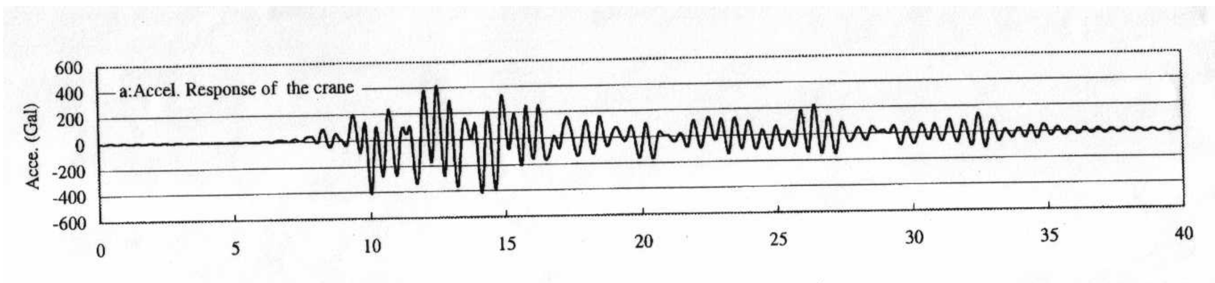
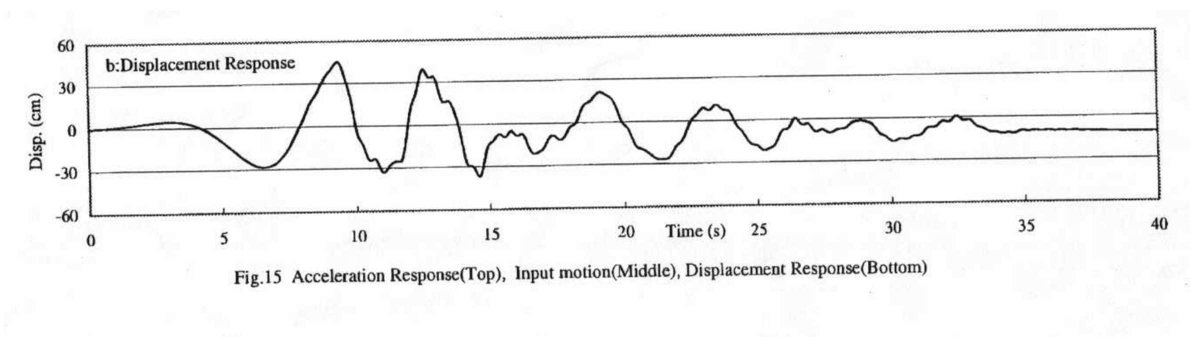


Figure 6.12 Mass-spring model of the crane



(a)Acceleration response



(b)Displacement response

Figure 6.13 Response analysis result

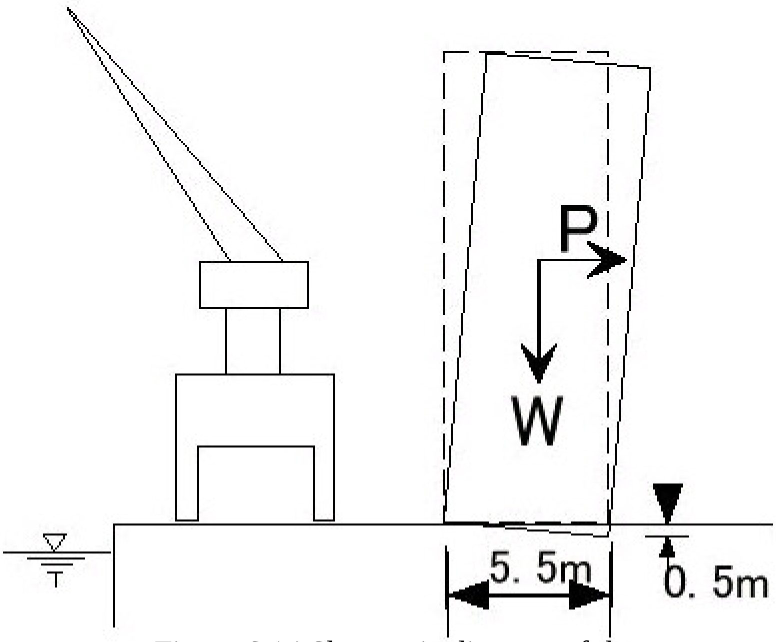


Figure 6.14 Shcematic diagram of the crane overturn

In case of overturned crane;

2.75W=7.0P

P=34.38t

P=W/g*A

A=337.0 Gal

In case of land side leg 0.5m settled condition,

P=29.22 t

A=28.0Gal

In case of standing crane next to the overturned crane with 0.5m settled condition, calculated in the same manner.

P=30.11 t

A=332.71 Gal

From the simple analyses, the performance of two cranes located side by side during the earthquake can estimated. However, the simple model analyses can not treat the rocking effect as legs uplift. To clear the overturning phenomena of the crane, more precious analysis such as dynamic3-D finite element method is needed.

6.3 Summary and Conclusions

(1) Derince Port: with PGA=0.25 to 0.3g, width to height ratio 1:3 or 4 cellular block type quay walls did not collapse. The underwater shake table test result shows the effect of the blocks stacked with 1 degree slant.
(2) Due to the constraint effect of slant stacking blocks, horizontal displacement and tilting angle are small.
(3) The steel pile supported wharves at Derince Port expressed good performance during the earthquake.
(4) No damage or slight damage to Haydarpasa port and other ports were find.
(5) From the function of port facilities point of view, it is important to consider the seismic performances of whole port facilities during earthquake such as dynamic interaction between crane and quay wall.
(6) Improvement of backfill soil is effective way to increase the performance of quay walls during earthquake
(7) In case of private port facilities such as factory’s port, the inspection of residual strength by specialists is needed.

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