Numerical Modeling Earthquake Effects On Sea Outfall Systems : Kadýköy Sea Outfall Case

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earthquake, discharge, tsunami, mathematical model

ABSTRACT
Earthquake effects have been evaluated by a numerical modeling study on the case of Kadýköy Sea Outfall Systems, Istanbul, Turkey. The main result has shown that sea bottom profile changes due to the tsunami height may cause a deep erosion in the sea outfall zone. Because the individual wave heights become larger as the waves approaching the shallower area. It has been shown that maximum amplitude may be 10 ~ 12 times higher than the open sea one and may be seen in the sea outfall zone. It has been concluded that the tsunami condition should be considered in the design stage of sea outfall systems as a wastal hazard.

INTRODUCTION

Disposal of wastewater in coastal areas is achieved in two ways: inshore or short discharges (≤ 500 m in length) and offshore or deep sea discharges (≥ 1300 m in length). Environmental assessment in both cases must be based on a review of their health, a esthetic, and ecological implications. The water quality objectives to be met are essentially derived from a need to project and promote the various beneficial uses to which the coastal water in question can be gut, and the likely impact that the wastewater disposal project may have on the microenvironment public health has long been the principal factor in ecological design for wastewater treatment and marine disposal systems. Marine outfall systems have been widely used as an effective and sustainable waste disposal alternative for the management effluents from coastal cities in many economically developed and developing countries.

Hydraulic performance of an outfall is usually quantified in terms of the dilution with a large number such as > 100 implying more complete mixing of the discharged effluent with marine water than a low number such as < 40. [1]

The structural design of marine outfall pipelines must take into account basic structural factors including installation problems, stress induced by anchoring if applicable, collapse/buckling analyses, unsupported pipe sprang and operational stresses due to environmental factors such as wave or current forces and/or soil forces.

In addition to the general causes of the discharge pipes faults, the earthquake effects have been a dominant parameters in the earthquake regions like Marmara Sea. Earthquake effects, as known, can at in two ways: (a) seismic motion (b) tsunami. The latter one is the most import parameters for discharge pipes stabilities because tsunami can produce large amount sediment transport resulting dramatize changes of sea bottom profile

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and it can magnify the hydrodynamic forces acting on the pipes. Because the discharge pipes generally are lined in trench and covered by armor layer the magnified forces may not be important. On the other hand, sea bottom profile changes may cause very serious problems. As known generally “Tsunami” is the Japanese name for the gravity wave system formed in the sea following any large scale, short-duration disturbance of the caused great damage and loss of life along oceanic shorelines, their relative infrequency and complex local behavior have resulted in widespread misconceptions as to their true nature-even among scientists. The following tentative description, based on very recent advances in tsunami research, will undoubtedly be modified as more data become available.

Tsunamis principally occur following undersea earthquakes of magnitude greater than 6.5 (Richter scale) having focal depths less than 50 km, although landslides, bottom slumping, and volcanic eruptions have been cited as primo-genitors in certain cases. Not all such earthquakes produce tsunamis, and the generation mechanism-which presumably is associated with vertical dislocations of the sea floor-undoubtedly differs from event to event. Since the majority of them originate at great depths in the sea, their precise origins will probably remain

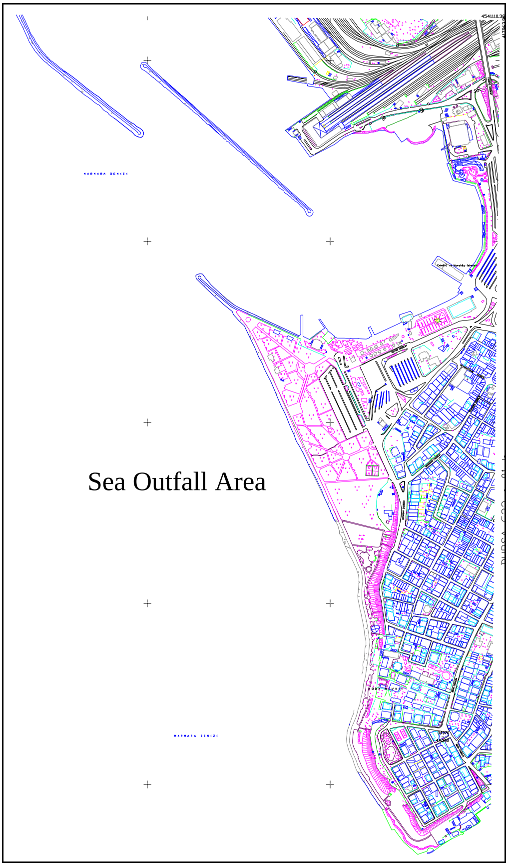


Figure 1The study area.

forever obscure. Once formed, however, the wave system resembles nothing so much as that produced by tossing a stone into the middle of a large shallow pond. In simplest aspect (more complex sources are thought to exist), the wave pattern is ax symmetric at early times, and consists of concentric rings of crests and troughs, bounded at the outside by an intangible “front”, that expands everywhere outwards at the limiting velocity $c_o = \sqrt{gh}$ for free waves in water of depth h (g = gravitational acceleration), and all subsequent waves travel more slowly. At any instant of time the radial separation between successive crests (wavelength) is largest near the front and becomes progressively smaller towards the center. In the absence of boundaries, which produce reflections, individual waves of the system retain their identity, in contrast to the wind-generated swell, which grows and disappears before the eye in the interval of a few seconds. [3]

As the waves approach the boundaries of ocean and pass into shallow water, the individual wave amplitudes become larger, because the energy increment contained within each wave is concentrated in an increasingly smaller volume of water. Eventually, as shoaling and wave growth continue, the wave amplitudes amount to an appreciable fraction of the water depth.

STUDY AREA

In this study, Kadýköy Sea Outfall Systems, which is located on Anatolia coast of Bosphorous, has been selected as the study area (Figure 1). This system has been under construction and its capacity 7.2 m^3sn^{-1} serving the region having the population of 2.230.000 persons in city Istanbul. The other diameter of discharge pipe is 2.2 m and its llenght 2.4 km. Biological treated wastewater will be discharged at the depth of –50m.

The sea bottom conditions are quite interesting such that it consists of very fine and movable sandy material and its mean slope approximately is about % 2. (Figure 2). For this reason the pipe has been hidden whole length of it.

METHODOLOGY

A numerical model study has been carried out in order to achieve the sea bottom profile changes under effects of tsunami, which may be seen after an earthquake occurred in Marmara Sea bottom because of the North Anatolia Fault. The numerical model used is cosmos, which has been developed by HR Wallingford, U.K. The model originally has been created for storm wave conditions but it has shown that it is also capably to tsunami conditions, which can simply be defined as long waves. [2]

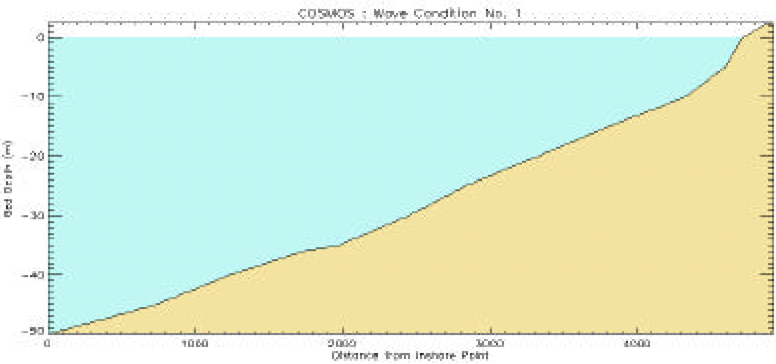


Figure 2 Sea bottom profile of Kadýköy coast.

Data about probable tsunami in Marmara Sea have been very limited. For this reason an approximate prediction has been made by using similar data obtained from the areas all over the world. Tsunami properties used in this study have been in between 1 cm and 1 m.

The digitized bathymetric maps of Marmara Sea have been taken from Turkish Navy, Oceanography and Hydrograph Department, Çubuklu, Ýstanbul. The generally bathymetric condition of Marmara Sea in the vicinity of the Bosphorous is given in Figure 3.

RESULTS

The results obtained by using numerical model have been introducing quite interesting conditions from discharge pipe stability point of view.

Tsunami magnitudes have been selected in between 0.1m and 1 m and the periods have been used 0.5 hours, 1 hour and 1.5 hours. The approaching angle, which is the measured as difference between wave orthogonal and the coastline, has been 15º, which is 230º from the North. These input data of numerical model have been quite sensible for a probable Marmara Sea earthquake.

The results obtained have been summarized in Table 1. Specifically, it can be mentioned that the wave run up changes in between 0.10 m and 2.2 m and that the maximum erosion may reach 25 m for maximum tsunami conditions. The range of sea bottom profile changes have been enlarged towards offshore while increasing tsunami magnitudes. This is because the higher waves can break in deeper water depth.

The numerical model has also been run for successive tsunamics with decreasing heights as expected in natural conditions. The final sea bottom profile has been obtained as the superposition of the maximum changes of each individual rather than that of the linear superposition.

It has been seen that the sea bottom profile has been formed a single sloped shape under successive tsunami effects.

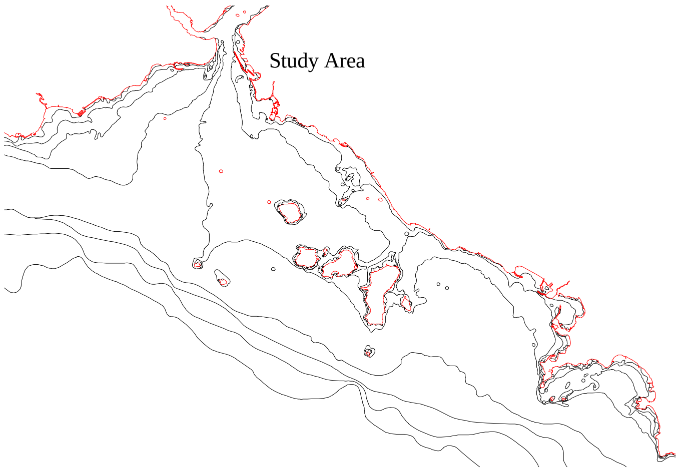


Figure 3 Bathymetry of Marmara Sea.

Table 1. The results of numerical modeling

KADIKÖY TSUNAMI ANALYSIS RESULT

Wave Direction: 230° from North

Wave Period: 0.5 hour

Wave Height (m)	Maximum Wave Height (m)	Maximum Wave Height's Depth (m)	Wave Set up (m)	Maximum Depth Evaluation (m)	Maximum Evaluation Depth (m)	Maximum Long shore Sediment Rate (m3/m/sn)	%50 Wave Breaking Depth (m)	%100 Wave Breaking Depth (m)	Pick Wave Orbital Velocity on bad (m/s)
0.01	0.64	1.67	0.09	0.002	2.08	5.30000E-06	2.00	1.25	0.78
0.05	2.3	6.16	0.38	0.085	5.19	7.87500E-04	6.82	5.98	1.48
0.10	4.01	10.49	0.55	0.153	10	2.28120E-03	11.88	10.38	1.96
0.30	9.67	25.29	1.1	0.249	30	2.10000E-02	28.87	25	3.04
0.50	14.58	38.36	1.38	0.426	35	4.67350E-02	43.92	38.2	3.73
0.70	19.73	49.33	1.61	> -4.80	> 50.00	3.7130	> 50.00	49.12	4.34
1.00	> 28.45	> 50.00	2.18	> -24.81	> 50.00	> 1.6870	> 50.00	> 50.00	> 5.30
0.5+0.3+0.1	14.58	38.36	1.38	0.46	35	1.92640E-03	28.5	24.6	3.73

Wave Direction: 230° from North

Wave Period: 1 hour

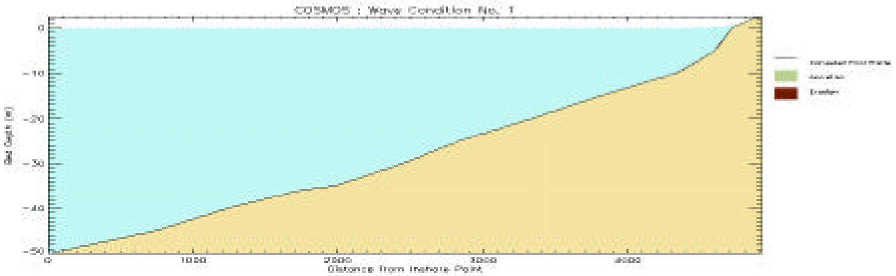
Wave Height (m)	Maximum Wave Height (m)	Maximum Wave Height's Depth (m)	Wave Set up (m)	Maximum Depth Evaluation (m)	Maximum Evaluation Depth (m)	Maximum Long shore Sediment Rate (m3/m/sn)	%50 Wave Breaking Depth (m)	%100 Wave Breaking Depth (m)	Pick Wave Orbital Velocity on bad (m/s)
0.01	0.84	1.67	0.09	0.003	2.09	5.29490E-06	1.96	1.25	0.78
0.05	2.31	6.15	0.38	0.14	5.19	5.01200E-04	6.84	5.96	1.48
0.10	4.02	10.57	0.55	0.196	10	1.23500E-03	11.89	10.48	1.96
0.30	9.72	25.28	1.09	0.29	35	1.22970E-02	29.49	25.26	3.05
0.50	14.63	38.58	1.39	0.55	35	3.11000E-02	44.06	38.33	3.74
0.70	19.97	48.86	1.66	> -7.32	> 50.00	> 0.27776	> 50.00	48.86	4.37
1.00	> 28.42	> 50.00	2.17	> -24.10	> 50.00	> 0.71495	> 50.00	49.85	> 5.32

Wave Direction: 230° from North

Wave Period: 1.5 hour

Wave Height (m)	Maximum Wave Height (m)	Maximum Wave Height's Depth (m)	Wave Set up (m)	Maximum Depth Evaluation (m)	Maximum Evaluation Depth (m)	Maximum Long shore Sediment Rate (m3/m/sn)	%50 Wave Breaking Depth (m)	%100 Wave Breaking Depth (m)	Pick Wave Orbital Velocity on bad (m/s)
0.01	0.64	1.66	0.09	0.002	2.09	3.73560E-05	1.95	1.25	0.78
0.05	2.31	6.15	0.38	0.18	5.19	3.90950E-04	6.84	5.97	1.48
0.10	4.03	10.58	0.55	0.28	10	9.47340E-04	11.91	10.48	1.96
0.30	9.72	25.37	1.09	0.32	35	8.95560E-03	29.08	25.14	3.05
0.50	14.65	38.67	1.39	0.67	35	2.86530E-02	44.13	38.41	3.75
0.70	20.1	48.56	1.7	> -8.76	> 50.00	> 0.2444	> 50.00	48.38	4.38
1.00	> 28.52	> 50.00	2.22	> -26.29	> 50.00	> 1.2660	> 50.00	> 50.00	> 5.27

H_{rms} = 10 cm



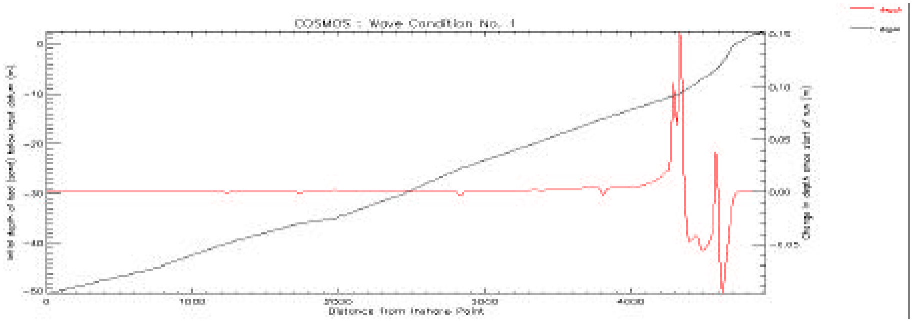
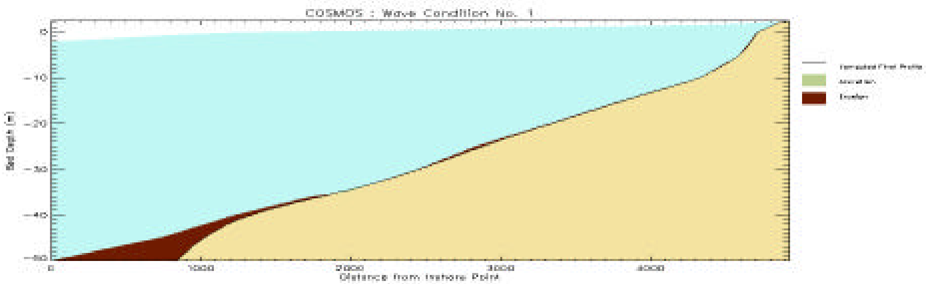


Figure 4 The result of the COSMOS module. Tsunami is affected in 1 hour. T=0,5 h, H= 10, 50 and 100 cm

H_{rms} = 100 cm



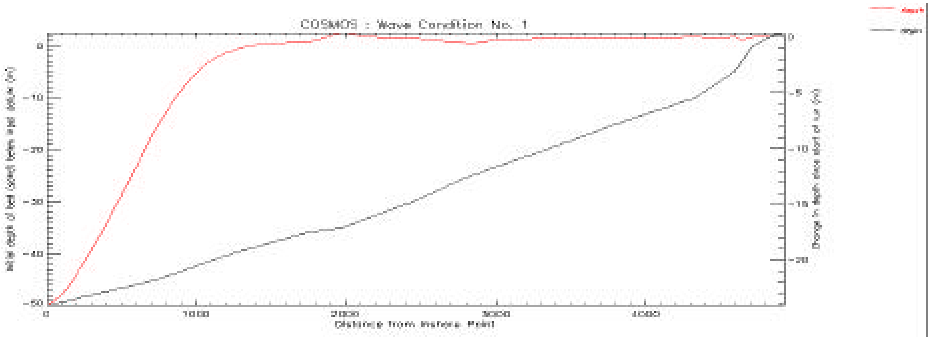


Figure 5. The result of the COSMOS module. Tsunami is affected in 2 hours. (T= 1 h, H= 10, 50 and 100 cm)

H_{rms} = 100 cm

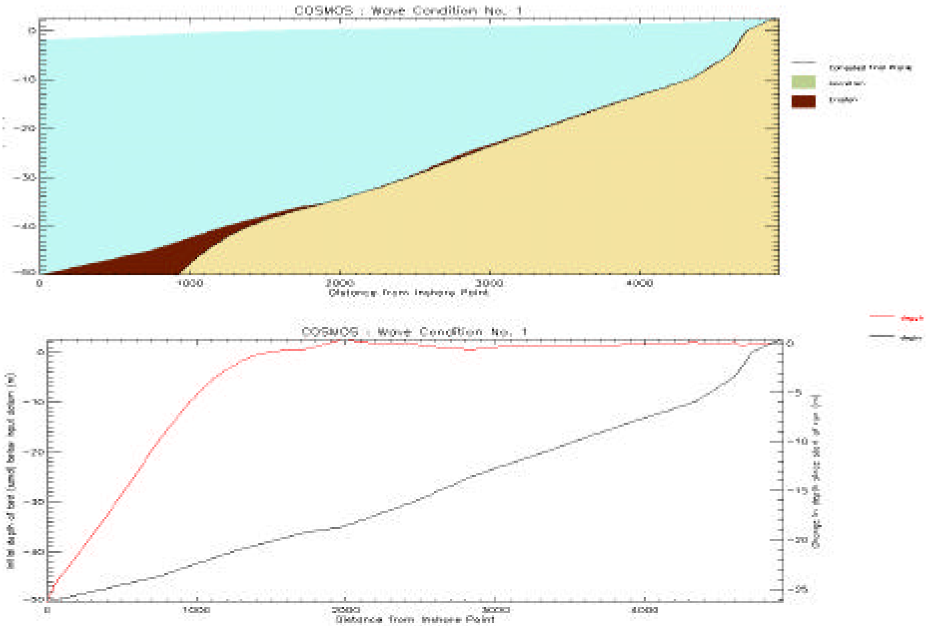


Figure 6 The result of COSMOS module. Tsunami is effected in 3 hours and wave highs are sequentially 1, 5, 10, 30, 50, 70, and 100 cm

Tsunami wave height changes while approaching the shoreline and increases so that its magnitude almost 10 ~ 15 times higher than that of the origin. The higher tsunami height can be seen at the location where sea bottom slope changes considerably. After this point tsunami height decreases towards shoreline down to 1.5 ~ 2 m.

During these change of tsunami magnitude sea bottom profile has also been changed.

Tsunami may have maximum height of 15 ~ 17 m at the depth of approximately – 40m area where 2 ~ 4 km from the coastline and may decrease such that its height is 5 ~ 6 m at –10 m depth almost 1000 m for from the coastline as seen in Figure 4, 5 and 6.

Moreover, during the tsunami cycle, peak orbital velocities can increase such that hydrodynamic conditions at the sea bottom shallower than – 40m are almost similar with the supercritical flow conditions in a river. That is why very strong and intensive sediment transport may be created.

While tsunami moves toward coastline, the cross-shore sediment discharge begins to oscillate and large amount of erosion is seen. The most critical area is between – 50 m and –40 m depth because the maximum wave height, minimum mean sea level, maximum change of water depth and maximum wave breaking ratio are seen in this area. If it is considered that the discharge depth is – 50 m and pipe length is 2.4 km for Kadýköy sea outfall system it can be seen that tsunami effects are so much important for this area under effects of 0.15 cm tsunami at the origin. But it is clear that the tsunami effects cannot be used as the dominant design criteria for planning the coastal structures including sea outfall systems.

The erosion area is given for Kadýköy coast as seen Figure 4. The results show that the erosion depth will be in between 1 m ~ 2 m depending on the tsunami heights.

Conclusions

A numerical model study has been carried at in order to evaluate the tsunami effects on sea outfall pipes by considering the Kadýköy sea outfall system conditions.

It can be concluded that tsunami may create very strong and intensive sea bottom motions and resulting profile changes. Such that discharge pipes may be uncovered conditions because of the armor layer. It can be considered that the floating pipe will be very fragile and be broken under hydrodynamics effects created by tsunami as well. On the other hand coastal structures cannot be designed by taken account of tsunami effects because of the cost and aesthetic reason. Tsunami should be considered in mitigation processes as a coastal hazard.

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