6 ŞUBAT 2023 TÜRKİYE-SURİYE DEPREMLERİ SONRASI HATAY-İSKENDERUN'DA DENİZ SEVİYESİ YÜKSELMESİNİN YAPISAL VE EKONOMİK ETKİLERİ

STRUCTURAL AND ECONOMIC EFFECTS OF SEA LEVEL RISING IN HATAY-ISKENDERUN AFTER 6 FEBRUARY 2023 TURKEY-SYRIA EARTHQUAKE

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ABSTRACT

On February 6, 2023, two earthquakes with magnitudes of 7.8 and 7.5 Mw occurred in Turkey, 9 hours apart. The earthquake epicentres were in the Pazarcık and Ekinözü districts of Kahramanmaraş. These earthquakes, which were felt across a large area and caused a considerable deal of destruction and damage, impacting 11 provinces, were particularly damaging to the province of Hatay. These earthquakes led to the deaths of more than 50,000 people in Turkey and around 9,000 people in Syria, as well as more than 120,000 injuries. Following the earthquakes, more than 33,000 aftershocks with magnitudes up to 6.7 Mw were recorded. As a result of the tectonic activity on land and under the sea, the mainland shifted to the west for meters, creating large rifts in the land. In the gulf region of the Iskenderun district of Hatay, subsidence and settlements occurred on the ground and the coastline changed. Following that, sea waves and flooding occurred due to northerly wind and the tide blowing from the sea to the land nearby. Subsequently, due to the northerly wind and tide blowing from the sea to the land in the region, sea swells and sea floods occurred. This situation caused the residential areas on the coast to be flooded. Due to the rise in the sea level, vehicle traffic was affected, the streets were flooded. The basement floors of shops, workplaces, hospitals, social facilities and residences facing the streets along the coast were filled with sea water and became unusable and people suffered substantial economic losses. Downfall in the structures and cracks in the walls were observed. The reinforcements in the foundation and columns began to corrode due to the salt water. Harbour, marina, boatyards, boats etc. were severely damaged. this study reveals the structural and economic effects of sea level rise in Iskenderun.

Keywords: February 6 2023 Turkiye-Syria earthquake, economic consequences, sea level rise, structural damages

ÖZET

Türkiye'de 6 Şubat 2023'te merkez üssü Kahramanmaraş'ın Pazarcık ve Ekinözü ilçeleri olan, ve 9 saat arayla 7,8 ve 7,5 Mw büyüklüklerinde iki deprem meydana geldi. Geniş bir coğrafyada hissedilen, 11 ili etkileyen çok büyük miktarda yıkım ve hasar meydana getiren bu depremlerden, özellikle Hatay ili daha fazla etkilendi. Sonuç olarak Türkiye'de 50 binden fazla, Suriye'de ise, 9000'e yakın kişi hayatını kaybetti ve toplam 120 binin üzerinde kişi ise, yaralandı. Depremlerin ardından büyüklüğü 6,7 Mw 'ye kadar ulaşan 33 binden fazla da artçı sarsıntı gerçekleşti. Kara ve denizaltındaki tektonik hareketlilik sonucunda ana kara batıya doğru metrelerce kayarak, arazilerde büyük yarıklar meydana geldi. Hatay'ın İskenderun ilçesi körfez bölgesinde zeminde çökme ve oturmaların meydana gelerek kıyı kenar çizgisi

değişime uğradı. Akabinde bölgede denizden karaya doğru esen poyraz rüzgarı ve gelgit nedeniyle deniz kabarması meydana geldi ve deniz taşkınları yaşandı. Bu durum kıyıda yer alan yerleşim alanlarının sular altında kalmasına neden oldu. Deniz seviyesinde meydana gelen yükselmeye bağlı olarak araç trafiği etkilendi, cadde ve sokakları su bastı, depremde yıkılmayan sağlam binaların bodrum ve zemin katları su ve balçıkla dolarak önemli oranda olumsuzluklar yaşandı ve insanlar büyük ekonomik kayba uğradı. Sahil boyu caddelere bakan dükkan, işyeri, hastane sosyal tesis ve konutların cadde seviyesinin altında olan katları deniz suyu ile dolarak ve kullanılmaz hale geldi. Yapılarda çökmeler duvarlarda çatlaklar oluştu. Tuzlu su yapı temeli ve kolonlarda donatılarda korozyon olayını başlattı. Yapılar değer kaybına uğradı alt katlar kullanılmaz hale geldi. Liman, yat limanı, balıkçı barınağı, çekek yerleri gibi kıyı yapıları ve burada bulunan sandal, tekne, yat vb. deniz yapıları da bundan etkilenerek önemli oranda zarara uğradı. Bu çalışmada İskenderun'da deniz seviyesi yükselmesinin yapısal ve ekonomik etkileri ortaya konmuştur.

Anahtar kelimeler: 6 Şubat 2023 Türkiye-Suriye Depremi, Ekonomik Etkiler, Deniz Seviyesi Yükselmesi, Yapısal Hasar

INTRODUCTION

There are multiple reasons for sea level rise. Global warming is one of the most important factors that cause sea level rise. Due to this development, which is called global climate change, there is an increase in temperature throughout the world. This causes the polar ice caps to melt and mix with the seas, and the volume of water increases and sea levels rise (Brown et al., 2021; Nicholls, 2003). Again, with the warming of ocean waters, thermal expansion occurs at the molecular level and the volume of seawater increases. The breaking of glaciers is another factor that raises sea levels. As large chunks of ice fall into the sea, the volume of water increases and the sea level rises (Silveira et al., 2021; Virkki et al., 2006). Again, due to climate change, certain locations see more rainfall, and the amount of water reservoirs like rivers and lakes also rises. Sea levels rise as a result of more water flowing into the ocean. The results of human activity also significantly contribute to sea level rise (Martyr-Koller et al., 2021; Paranunzio et al., 2022).

Another reason for sea level rise is coastal erosion and marine pollution (Magnan et al., 2022; Martyr-Koller et al., 2021). As a result of erosion, coastal soil and coastal structures are eroded towards the sea, the shoreline recedes and sea level rises closer to the shore. The combination of these factors leads to gradual rise in sea levels and more frequent flooding and flooding in coastal areas. There is also a relationship between earthquake and sea level, but this relationship is complex and affected by many factors. These factors include Tsunamis, seafloor movements, submarine volcanoes and crustal movements (Cetin et al., 2023)

Large-scale earthquakes can cause tsunamis with ruptures in the seafloor. Tsunamis can cause a sudden rise in sea level followed by large waves reaching coastal areas (Martyr-Koller et al., 2021). Earthquakes can also affect sea level due to movements of the earth's crust on the seafloor. A severe earthquake can move the earth's crust up or down along with ruptures in the seafloor, causing local sea level changes. Earth's crust movements in the area affected by the earthquake can cause the coastline to rise or fall, which can lead to long-term changes in sea level. Some earthquakes occur as a result of submarine volcanic activity. Such earthquakes can cause sea level fluctuations through the impact of magma on the earth's crust. These factors play an important role in explaining the relationship between earthquakes and sea level. However, because the relationship between earthquakes and sea level is very complex (Cetin et al., 2023), it should be kept in mind that not all earthquakes will cause major changes in sea level, or in some cases even small earthquakes can have significant effects on sea level. Recent Turkey earthquake showed the consequence of tsunami in the port of Iskenderun. Figure 1 shows the highest water height and the location of a potential tsunami source. The timings that the waves arrived at the four tide gauges suggest that a tsunami may have originated north of Samanda around Kale Cape, from a source with a bipolar elliptical subsidence and uplift form.

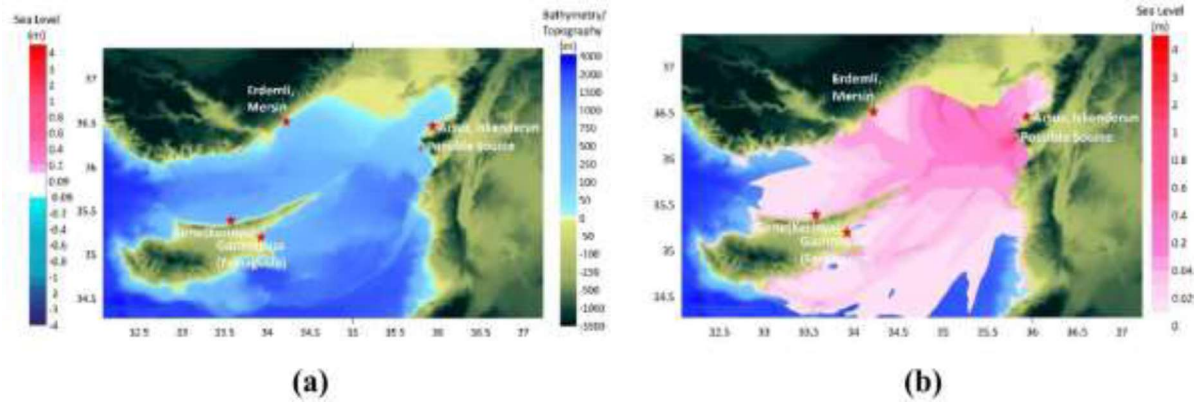

Figure 1. Showing (a) tide gauge stations and the location of the potential small-amplitude tsunami source, (b) maximum water elevation distribution calculated from the potential source, north of Cevlik (Cetin et al., 2023)

STUDY AREA

Iskenderun is the largest district of Hatay province, located on the Mediterranean coast in the south of Turkey, and is approximately 40 kilometers from the center of Hatay (Figure 2). The city is considered one of the important port cities of the Eastern Mediterranean and is very close to the Syrian border. Turkey's largest port, strategically located on the Iskenderun Bay, is in this city. Iskenderun is in an advantageous position in terms of both trade and tourism. Being located in the Southeast Anatolian Region facilitates transportation to the inner parts and the Middle East. Before the earthquake, the city's coastline and tourist areas were attractive holiday destinations for domestic and foreign tourists (SSB, 2023). But after the earthquake, dozens of buildings collapsed, sea floods occurred and affected all structures at sea level (AFAD, 2023). At present, efforts are being made to heal the wounds of the earthquake, to repair the damaged buildings, to clear the debris of heavily damaged buildings, and to return the city to its old days (Cetin et al., 2023).



Figure 2. The map of Iskenderun/Hatay city

Aftermath of the flood

There may be different reasons for the rise of sea level in this season. Better conclusions can be drawn after detail investigation are done. However, it seems that due to the earthquake, collapses of approximately 1.5 m in places on the coastal level and in the structures on the coastline, settlements formed around 1 m, and then due to the northerly wind, the sea level rose on the Iskenderun coast, and a sea flood occurred and the lower floors of all the buildings on the coast were flooded.

Some streets, houses and businesses were submerged. Due to the puddles formed on the streets and roads, vehicle drivers and pedestrians have had difficulty in advancing in traffic (Figure 3).



Figure 3. Drone view of damaged Hatay/Iskenderun coast (SonDakikaNews, 2023)



Figure 4. Damaged street view of Hatay/Iskenderun (SonDakikaNews, 2023)

After the earthquake on February 6, 2023, with the sea level rise on the coastal road, the sea water, which penetrated 200 meters, reached the 4th floor of some buildings in some districts, and the housing estates, banks and workplaces on the boulevard were urgently evacuated (Figure 4). However, the sea water receded from the coast on the 4th day of the earthquake and was replaced by mud and it was almost as if the whole place was covered with mud.



Figure 5. Damages due to seawater rise in Hatay/Iskenderun (SonDakikaNews, 2023)

Especially the port of Iskenderun, which is the largest port of Turkey, was flooded, after the collapses and settlements in places, the port traffic completely stopped, the infrastructure and electrical system were damaged and all tools and equipment were damaged. After the earthquake, the containers overturned and a fire broke out in the container yard at the port. With the help of all the fire brigades in the region, the ongoing fire could only be extinguished days later. Fishermen's shelters have become unusable. Some of the fishing boats in the shelters severely damaged as a result of collisions and displacements after the earthquake (SSB, 2023) (Figure 6 and Figure 7).



Figure 6. Damage due to seawater rise at İskenderun city port (SonDakikaNews, 2023)



Figure 7. Damage to the building at İskenderun Fishery Port (Cetin et al., 2023)

CONCLUSION and RECOMMENDATIONS

- One of the main reasons for sea floods to overwhelm residential areas is the change of the coastline and the opening of the areas within the coastline to zoning and the presence of construction in these areas.
- Adding to this, the collapses caused by the earthquake in this area will result in inevitable flooding.
- Sea water coming into contact with the building elements can cause various damages to the durability of the structures and the life of the materials.
- Some of the damages that seawater can cause to the structure include corrosion, electrical faults, deterioration in concrete, deterioration in wood, erosion of coastal structures, fatigue in structures and materials.
- Salt and other chemical components in seawater can cause corrosion on metal materials in the structure. This means that metals oxidize and rot. Corrosion can affect steel structures, pipes, seaports and other marine structures.
- Seawater can reduce the durability of concrete structures. The water in the concrete attracts the salts in the sea water and these salts accumulate inside the concrete. This process weakens the internal structure of the concrete and can cause cracks to form.
- Seawater can also cause rusted metals on concrete surfaces to rot.
- Seawater can cause deterioration of wooden structures. Continuous exposure can cause wood materials to swell, rot and crack.
- Salts in seawater can also damage paints and coatings on wood.
- Seawater and waves can erode the coastline and coastal structures. Soil and sand can be lost by wave action, so the shoreline can recede and structures can be endangered.
- Structures under sea water are constantly under the influence of waves and tides.

- This constant movement can cause structures to suffer fatigue damage.
- The effect of waves, sea level rise and currents can cause damage or even collapse of coastal structures (e.g. coast guards, piers, breakwaters).
- Seawater can damage the electrical systems of buildings in an electrical environment. Electrical wiring and other components that come into contact with seawater can cause short circuits, malfunctions, and electrical fires.
- Damages such as corrosion, deterioration of concrete, deterioration of wood, erosion of coastal structures, fatigue in structures and materials, electrical faults, which are counted among the damages that sea water can cause, can reduce the durability of the structures, shorten their life and endanger their structural integrity and increase the frequency of maintenance work.
- It is important that structures in contact with sea water are regularly maintained and repaired and appropriate protection measures are taken.
- In addition, measures can be taken, such as the use of seawater resistant materials and the application of protective coatings.

REFERENCES

AFAD. (2023). *Disaster and Emergency Management Presidency of Turkey. "Kahramanmaraş'ta Meydana Gelen Depremler Hk. – Basın Bülteni 36", Available From:https://www.afad.gov.tr/kahramanmarasta-meydana-gelen-depremler-hk-36*.

Brown, S., Jenkins, K., Goodwin, P., Lincke, D., Vafeidis, A. T., Tol, R. S. J., Jenkins, R., Warren, R., Nicholls, R. J., Jevrejeva, S., Arcilla, A. S., & Haigh, I. D. (2021). Global costs of protecting against sea-level rise at 1 . 5. *Climatic Change*, 1–21.

Cetin, K. ., Ilgac, M., Can, G., & Cakar, E. (2023). *Preliminary Reconnaissance Report on February 6, 2023, Pazarcık Mw=7.7 and Elbistan Mw=7.6, Kahramanmaraş-Türkiye Earthquakes*.

Magnan, A. K., Oppenheimer, M., Garschagen, M., Buchanan, M. K., Duvat, V. K. E., Forbes, D. L., Ford, J. D., Lambert, E., Petzold, J., Renaud, F. G., Sebesvari, Z., van de Wal, R. S. W., Hinkel, J., & Pörtner, H. O. (2022). Sea level rise risks and societal adaptation benefits in low-lying coastal areas. In Scientific Reports (Vol. 12, Issue 1). Nature Publishing Group UK. doi: 10.1038/s41598-022-14303-w

Martyr-Koller, R., Thomas, A., Schleussner, C. F., Nauels, A., & Lissner, T. (2021). Loss and damage implications of sea-level rise on Small Island Developing States. *Current Opinion in Environmental Sustainability*, *50*, 245–259. doi: 10.1016/j.cosust.2021.05.001

Nicholls, R. J. (2003). Case study on sea-level rise impacts. In Environment (Vol. 9). Retrieved from http://www.oecd.org/env/cc/2483213.pdf

Paranunzio, R., Guerrini, M., Dwyer, E., Alexander, P. J., & O'Dwyer, B. (2022). Assessing Coastal Flood Risk in a Changing Climate for Dublin, Ireland. *Journal of Marine Science and Engineering*, *10*(11). doi: 10.3390/jmse10111715

Silveira, F., Lopes, C. L., Pinheiro, J. P., Pereira, H., & Dias, J. M. (2021). Coastal Floods Induced by Mean Sea Level Rise—Ecological and Socioeconomic Impacts on a Mesotidal Lagoon. *Journal of Marine Science and Engineering*, *9*(12). doi: 10.3390/jmse9121430

SonDakikaNews. (2023). *Accessed on June 10, 2023, Available from https://www.sondakika.com/haber/haber-deniz-seviyesinin-yukseldigi-iskenderun-da-binalar-15617426/.*

SSB. (2023). *2023 Kahramanmaraş and Hatay Earthquakes Report* (Issue March). Retrieved from https://www.sbb.gov.tr/wp-content/uploads/2023/03/2023-Kahramanmaras-and-Hatay-Earthquakes-Report.pdf

Virkki, H., Kallio, H., & Orenius, O. (2006). Sea level rise and flood risk assessment in Itä-Uusimaa. *Special Paper of the Geological Survey of Finland*, *41*, 95–106.