UNESCO Chair on
Coastal Geo-Hazard Analysis
Research Institute for Earth Sciences
Geological Survey of Iran

Abstract:

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Collection of Geophysical data by high-resolution Shallow Seismic method in Tombak region (Bushehr Province) with an attitude on Seismotectonic and Morphotectonic Characteristics

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Collection of geophysical data by high-resolution shallow seismic method in Tombak region (Bushehr province) with an attitude on seismotectonic and morphotectonic characteristics

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Collection of geophysical data by high-resolution shallow seismic method in Tombak region (Bushehr province) with an attitude on seismotectonic and morphotectonic characteristics

Author: Reza Behbahani

نشرخزه

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segment, are not observed. However, the presence of high-angle step-like features in the eastern part of the studied area can be caused by coastal sedimentation, strong tidal currents, or the action of the thrust fault.

Introduction:

The studied area is located near Tombak village and Bandar-e Kangan, Bushehr province, with the coordinates of 52 12 E, 27 41 N in the Zagros fold belt and in the leading front of this folding on the coast of the Persian Gulf. The Kangan County is located in the southeastern part of Bushehr province, and its distance to the capital city of the province, i.e. Bushehr city, is about 200 kilometers and the approximate height above sea level is about 20 meters. This city is one of the oldest ports in Iran and has a long history of trade and includes significant industrial and agricultural sectors. Since this city is located on the coastal part of the province, it has hot and humid weather. The most important tectonic structure of the region is the Kangan anticline.

Tectonic characteristics of Zagros:

The studied area is located in the Zagros structural zone. Structurally, from the northeast to the southwest, Zagros includes thrust zone, fold belt, embayment and a flat area (Abadan Plain) (Mouthereau et al., 2006). The Zagros fold-thrust belt is the result of the continent-continent collision between the Eurasian and Arabian plates following the closure of the Neo-

Tethys Ocean during the Tertiary (Figure 1) (Mouthereau et al., 2006). This belt stretches from the Strait of Hormuz to the eastern coast of the Mediterranean Sea (about 2000 km). This belt is classified into structural subdivisions (such as Dezful Embayment, High Zagros, Lurestan and Fars Arcs and Kirkuk Embayment) (Pirouz, 2018) (Figure 2). Despite some debate about the timing of collision (Hesami et al., 2001), there are doubts about the main phase involving shortening within the Zagros fold belt about ten million years ago by the youngest folded strata of the Aghajari Formation. According to the studies of the Global Positioning System, the shortening of about seventy kilometers resulted from the balanced parts of the Zagros folded belt with a continuous shortening rate of seven kilometers per million years (with today's rate of 0.7 cm per year) has been established (Vernant et al., 2004). The major discontinuity between the Aghajari Formation and the Bakhtiari Formation indicates the reduction or cessation of shortening in the last 5 million years. During or since the beginning of the deposition of Bakhtiari Formation, the Zagros fold belt has undergone a regional uplift of uncertain origin (Mouthereau et al., 2006). This belt is located on the northeastern margin of the Arabian Plate on the basement of the Precambrian. Also, this belt was thickening as a result of the collision between the central Iran and Arabian plates (Berberian, 1995).

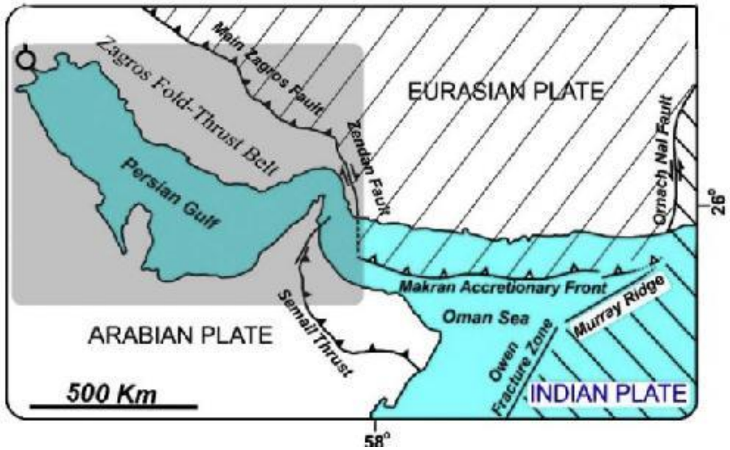

Figure 1: Location of the Zagros fold-thrust belt (Orang et al., 2018).

Figure 2: Structural subdivisions of the Zagros fold-thrust belt (Pirouz, 2018).

Tectonic setting of the studied area:

The studied site in this research is located on the front of the Zagros fold and on the coast of the Persian Gulf, on the southeastern flank of the Kangan anticline, and follows the general geological and seismotectonic features of this area. The Kangan anticline is one of the largest anticlines in the gas fields in the south of Iran. This anticline is part of the Fars platform and part of the southeastern margin of the Zagros Mountain Range, which is located on the mountain front of these heights and next to the Persian Gulf. In terms of morphotectonics, the Kangan anticline represents the front of the Zagros fold in this region, and its genesis is under the control of a hidden basement thrust called the Kangan segment from the Mountain Front Fault (MFF) (Berberian, 1995), in such a way that the site and the studied area are located on its footwall (Figure 3). In addition, the Asaluyeh segment is also close to the wharf under construction.

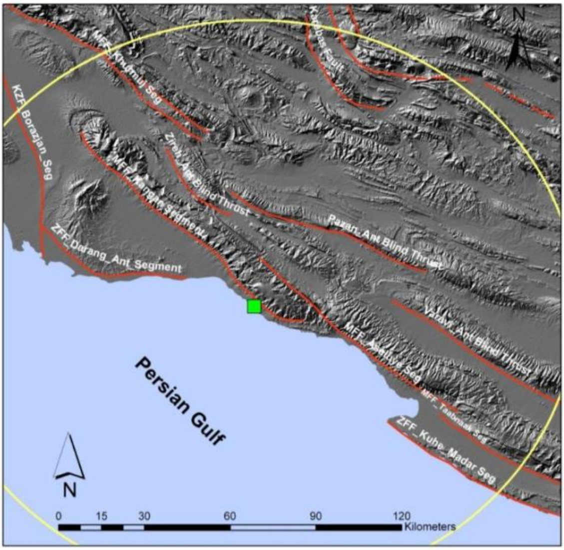

Figure 3: Location map of main faults near the studied area on SRTM digital topographic data. Red lines, thrust faults and green squares are the approximate studied area. The Darang segment from the Main Zagros Foredeep Fault, the eastern part of the Kangan segment from the Main Zagros Mountain Front Fault, the Asaluyeh segment from the Main Zagros Mountain Front Fault and the Kuh-e Madar segment from the Main Zagros Foredeep Fault are located along and near the southern coast of Iran (Bushehr Province). The studied area is located in the activity area of the Kangan segment.

Materials and Methods:

In order to study the bottom characteristics of the studied area, high-resolution shallow seismic data, collected by Sub-Bottom Profiler SES-2000 Standard made by INNOMAR Technologie, Germany, have been used. The frequency range used in this device varies between 4-12 KHZ, and in this series of data, three frequencies of 4, 8 and 12 KHZ have been used and due to the use of two frequencies close to each other and the special type of their combination, the adverse effects common in other existing acoustic devices have been reduced as much as possible. The separation power of this device in the vertical direction is less than 10 cm, and the penetration depth of surveys is up to 50 meters in soft sediments in ideal conditions. Seismic lines were taken in an area of 1.43 square kilometers in Tombak Port. These surveys were carried out in a relatively regular network including 101 lines at an approximate distance of 25 meters and a total of nearly 70 linear kilometers were surveyed (Figure 4).

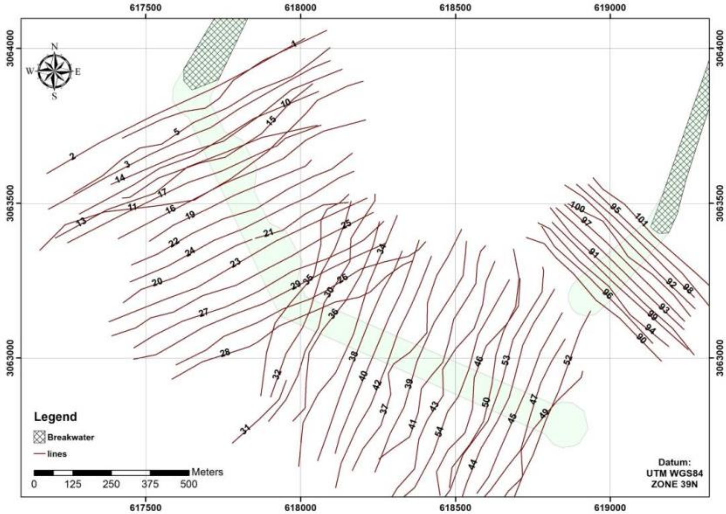

Figure 4: The location of some profiles in Tombak Port.

It should be noted that due to the low maneuverability of the used vessels and the low extent of the studied area, the profiles are not completely "perpendicular" to the coast. It should be mentioned that in order to accurately check the bottom and the sub-bottom sedimentary layers, it has been tried to study 6 relatively perpendicular lines to the breakwaters (Figure 5).

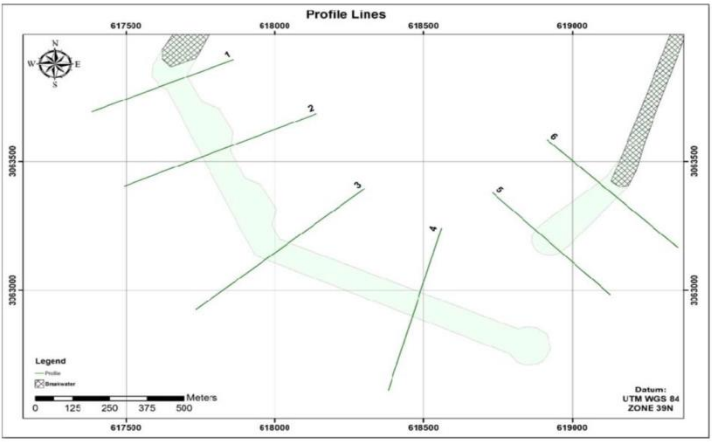

Figure 5: The position of "completely perpendicular" profiles in Tombak Port (Bushehr province).

The movement of recent faults in the area can endanger the stability of the structures and thus the life safety. If a fault has signs of movement during the Holocene (in the last 11 thousand years), there is a possibility of its reactivation during the useful life of the structure, and therefore it is considered a recent fault. It is preferable that the structure is not designed and executed on such faults, or if the structure is built, the necessary arrangements should be made. Therefore, it is important to identify recent faults in this area.

Bathymetry of the studied area:

In geophysical surveys, depth information is also collected, and due to the high accuracy of this information, iso-depth maps are prepared at the beginning of data processing. In these maps, the areas that have been riprapped for the construction of breakwaters can be seen in terms of height (Figure 6). In addition, Digital height basis for preparing hydrographic map is Kangan station, which the information was obtained from the National Iranian Cartographic Center.

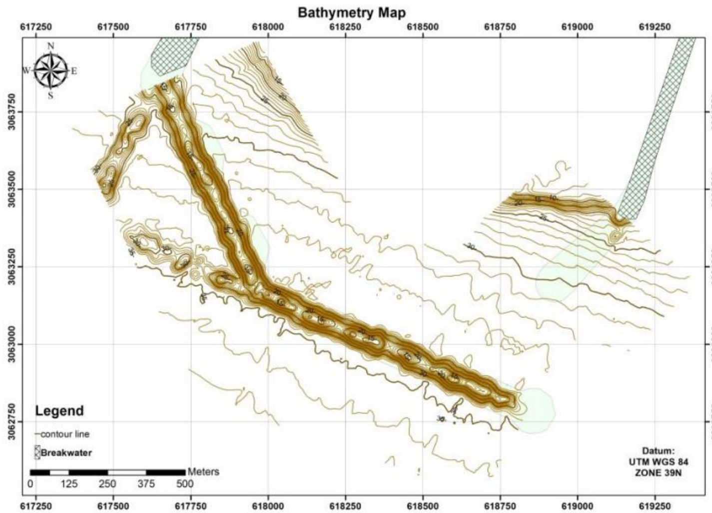

Figure 6: Bathymetric map as iso-depth contours.

Identification of subsurface sedimentary units in Tombak Port

By examining the seismic data collected in Tombak Port, 3 subsurface sedimentary units were identified. Next, the position of the seabed, the thickness of the sedimentary units and the height of the ridge (areas filled with rock fragments for the construction of pillars of wharf) of the lines surveyed perpendicular to the western and eastern breakwaters of the studied structure (Figure 5) are given in detail.

Line 1 (northeast-southwest direction): seabed at a water depth of 28 to 30 meters, the height of the rock-filled areas is 12 to 15 meters, the thickness of unit 1 is about 10 meters, the thickness of unit 2 is about 6 meters, and the thickness of unit 3 is not known due to the lack of penetration of seismic data in greater depths and the lack of recognition of its lower surface (Figure 7).

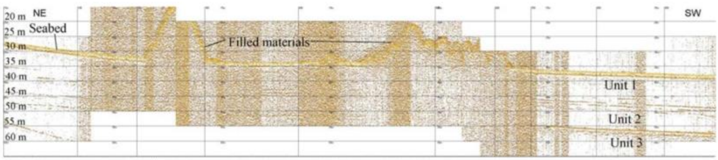

Figure 7: The position and thickness of the sedimentary units, the position of the seabed and the height of the areas filled with rock fragments in line 1. The seabed is located at a depth of 28 to 30 meters.

Line 2 (northeast-southwest direction): seabed at a water depth of 31 to 33 meters, the height of the rock-filled areas is 18 meters, the thickness of unit 1 is about

10 meters, the thickness of unit 2 is about 8 meters, and thickness of unit 3 similar to line 1 is not known (Figure 8).

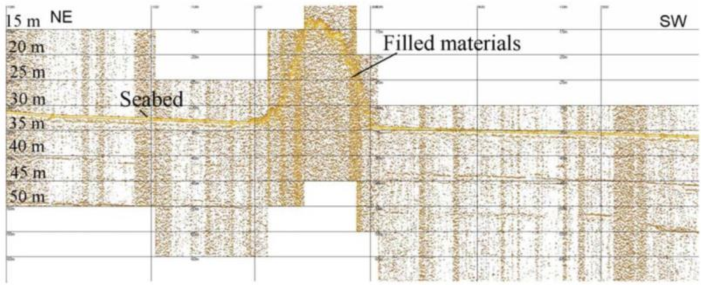

Figure 8: The position and thickness of the sedimentary units, the position of the seabed and the height of the areas filled with rock fragments in line 2. The seabed is located at a depth of 31 to 33 meters.

Line 3 (northeast-southwest direction): seabed at a water depth of 31 to 33 meters, the height of the rock-filled areas is 14 meters, the thickness of unit 1 is about 9 meters, the thickness of unit 2 is about 9 meters, and the thickness of unit 3 similar to the lines 1 and 2 is not clear.

Line 4 (northeast-southwest direction): seabed at a water depth of 31 to 33 meters, the height of the rock-filled areas is 12 meters, the thickness of unit 1 is about 8 meters, the thickness of unit 2 is about 10 meters, and the thickness of unit 3 similar to the previous ones are not clear.

Line 5 (northwest-southeast direction): seabed at a water depth of 29 to 30 meters, lack of rock-filled areas, the thickness of unit 1 is about 21 meters, lack of unit 2 and the thickness of unit 3 similar to the previous lines is not clear.

Line 6 (northwest-southeast direction): seabed at a water depth of 8 to 28 meters, the height of the rock-filled areas is about 5 meters, the bed has a steepened step-like feature from the depth of 10 to 23 meters, the thickness of unit 1 is between 8 to 30 meters and units 2 and 3 cannot be recognized due to the seabed multiple (Figure 9).

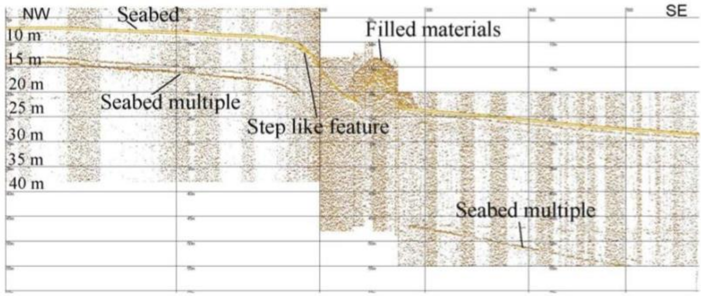

Figure 9: The position and thickness of the sedimentary units, the position of the seabed and the height of the areas filled with rock fragments in line 6. The seabed is located at a depth of 8 to 28 meters. The bed in this line has a steepened step-like form from the water depth of 10 to 23 meters. Due to the multiple phenomenon, subsurface units 2 and 3 are not observed.

Line 90 (northwest-southeast direction; Figure 4): seabed at a water depth of 11 to 33 meters, the height of the rock-filled areas is about 15 meters, the bed has a steepened step-like feature from a depth of 12 to 27 meters, the thickness of unit 1 is about 7 meters, the thickness of unit 2 is about 10 meters, and the thickness of unit 3 is unrecognizable (Figure 10).

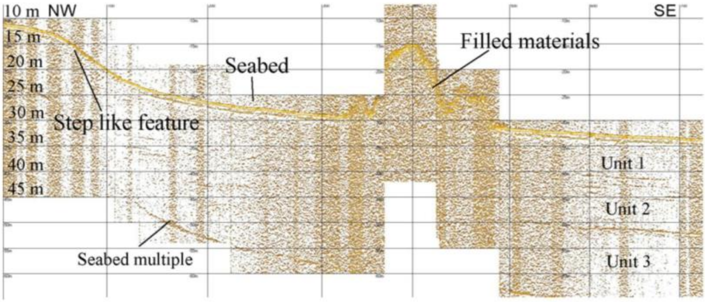

Figure 10: The position and thickness of the sedimentary units, the position of the seabed and the height of the areas filled with rock fragments in line 90. The seabed is located at a depth of 11 to 33 meters. The bed in this line has a steepened step-like form from the water depth of 12 to 27 meters. Due to the multiple phenomenon, subsurface units 1, 2 and 3 can be separated well in this line.

Discussion:

From a structural point of view, the studied area is located in a shallow sea zone that is developed in the southwest of the Kangan anticline, the southeast of the Kangan segment, and the south of the Asaluyeh segment (Figure 3). In the seismic data collected in the area of the wharf, there are no signs indicating the presence of active faults under the site area or around it. Also, in the recorded seismic lines, displacement in sedimentary layers, discontinuity of seismic data, and interruption based on the action of active faults in the area especially the Kangan segment are not seen. However, the existence of a steepened step-like feature (a feature with a relatively steepened slope) in the eastern part of the study area, according to the tectonic information of the area, may be due to the action of a thrust fault whose slope is towards the north and opposite to the topographic slope of step-like feature. Also, the presence of this steepened feature may be a result of coastal sedimentation (Behbahani and Lak, 2020), hydrodynamic processes and sediment distribution due to existing strong tidal currents (Behbahani et al., 2015) in the Persian Gulf. It should be mentioned that if there are non-significant branches of the Kangan segment under the sediments on which the structure is built, their displacement is much less than the displacement of the main fault. Based on the experimental relations of Wells and Coppersmith (1994), the average and maximum displacement of this fault during its future movements are estimated to be 67 and 162 cm respectively on the main Kangan fault (Petropars and Horizon, 2008). In addition, according to the history of active faults in the region (Berberian, 1995) and the presence of salt layers of the Hormuz series at high depth (Mouthereau et al., 2006) and the tendency of these layers to absorb surface waves from earthquake , and as a result, weaker waves reaching the surface layers (damping of surface waves), the maximum magnitude of the earthquake occurred in the studied area (30 km from the wharf) according to the available information, was 5.8 on the Richter scale and thus there is a very low probability of the occurrence of earthquakes with a magnitude greater than 6 on the Richter scale in the region.

Conclusion:

According to the information extracted from seismic data, three subsurface sedimentary units have been identified in Tombak Port. Unit 1 (the upper surface of unit 1 is considered to be the same as the seabed surface) with a thickness between 6.5 and 10.5 meters in the western breakwater and a thickness between 8 and 30 meters in the eastern breakwater, and unit 2 with a thickness between 6 to 10.5 meters in the western breakwater and a thickness of 10 meters in some seismic lines of the eastern breakwater have been observed. The thickness of layer 3 cannot be calculated due to the lack of observation of its lower boundary.Considering the lack of evidence of the presence of active faults under the area of the wharf under construction, such as displacement in the sedimentary layers and discontinuity and interruption of seismic data, there are no indications of the activity of the Kangan segment in the region. The presence of steepened step-like feature in some of the seismic lines in the eastern part of the wharf may be a sign of the action of the thrust fault, coastal sedimentation, hydrodynamic processes and the distribution of sediments due to strong tidal currents.

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