International Journal of Offshore and Polar Engineering
Vol. 5, No. 2, June 1995 (ISSN 1053-5381)

Oceanographic Measurements for the Tube-Tunnel Crossing of the Bosphorus

Adnan Akyarlì* and Yalçìn Arìsoy
Dokuz Eylül University, Institute of Marine Science and Technology, İzmir, Turkey

ABSTRACT

The Bosphorus is among the major components of the Mediterranean-Aegean-Dardanelles-Marmara-Bosphorus-Black Sea system through which exchange of water between the Mediterranean and Black Seas occurs. At its southern entrance, a tube-tunnel crossing of the Bosphorus has been designed, and the Institute of Marine Science and Technology of Dokuz Eylül University, İzmir, Turkey (IMST) has conducted comprehensive oceanographic measurement campaigns to assess the environmental impacts of this project (Arìsoy and Akyarlì, 1990). This paper summarizes the studies conducted in this respect to complement the authors' recent paper on the hydrodynamic characteristics of the BMJ area, which comprises the Sea of Marmara and the Bosphorus junction (Akyarlì and Arìsoy, 1993) and outlines the contribution of the IMST's surveys to an understanding of the complex two-layer flow system in the Bosphorus with a particular emphasis on the blocking phenomenon, which corresponds to an exceptional case due to the stopping of the lower layer flow before reaching the Black Sea.

INTRODUCTION

The Bosphorus is the strait between the Black Sea and Sea of Marmara; it is nearly 31 km in length; its width varies between 0.7 and 3.5 km, and mean and maximum depths are 35 m and 110 m, respectively. Here, while the narrowest width occurs at about 12 km north of the southern end, two sills exist with 33-m water depth approximately 3 km north of the same end and with 60-m water depth located 4 km north of the northern end (Ünlüata, Oğuz, Latif, and Özsoy, 1990).

The Black Sea is a northeastward extension of the Mediterranean into southeastern Europe. It extends in an east-west direction from longitude 28° E to 42° E, a distance of about 600 nautical miles, and in a north-south direction from latitude 41° N to 47° N, a distance of about 350 nautical miles (Akyarlì, 1993). While the surface area of the Black Sea is 426.000 km^2 together with the Sea of Azov, it holds 537.000 km^3 of water. Average water depth is 1271 m in the Black Sea depression; it increases towards the south and reaches its maximum of 2245 m around the central portion. The length of shoreline, according to various authors, is 4020 to 4100 km.

On the other hand, the Sea of Marmara is a relatively small intercontinental basin with a surface area of 11500 km^2 and a volume of 3378 km^3. It is also connected to the Aegean and consequently to the Mediterranean Sea via the strait of Dardanelles. The east-west length of the basin is roughly 240 km; the north-south width, about 70 km. The North Anatolian fault crosses the region in an east-west direction, and "pull-apart" basins associated with this fault are located on the northern side of the sea. Here, three sub-basins with water depths in excess of 1000 m (maximum 1300 m) have been formed, oriented also in an east-west direction. The southern half of the Marmara Sea is characterized by a relatively shallow shelf region with an average depth of 100 m. While the length of European shoreline is 264 km, it is 663 km along the Asian coast (Ünlüata, Oğuz, Latif and Özsoy, 1990).

In addition to its significance as a natural navigation channel between the Black Sea and the Sea of Marmara, the Bosphorus is also a promising area for marine structures, such as the tube-tunnel crossing located close to its southern entrance, and a number of marine outfall systems located alongside it, which are foreseen within the Istanbul Sewerage Project (Fig. 1) (DAMOC, 1971). The tube-tunnel is an underground facility 12.5 km in length where a 2 km-long crossing under the Bosphorus will be a binocular immersed tube-tunnel (Fig. 1). It has been planned to connect the existing railroads at the European and Asian sides of Istanbul (IRTC, 1988), and hence to improve the public transportation system of the city in combination with the Istanbul metro system, which is the major component of the same project.

The philosophy beyond the sewage project is based on the discharge of wastewater into the bottom layer flow in the Bosphorus to transport the sewage into the deeper anoxic layers of the Black Sea. However, there are various opinions on the probability of the blocking of the lower layer flow at the northern sill. Such an occurrence naturally seems risky, because wastewater will not be able to reach the Black Sea when the blocking conditions happen.

The accepted theories on the two-layer flow in the Bosphorus assume that the flow is controlled by the critical sections. The hypothetical control sections and general features derived from various surveys in the Bosphorus are schematized in Fig. 2. At the southern end, the abrupt widening at the exit and the sill slightly to the north of it are so close to each other that their influences on the flow can not be distinguished from each other. Therefore, a combination of the two effects can be lumped together to a hypothetical control section located in the vicinity. The second probable location of a control section is the contraction located in the southern half of the Bosphorus. Finally, the third possible location is the abrupt Black Sea exit envisioned to act together with the sill slightly to the north (Özsoy et al., 1986; Oğuz et al., 1990).

The proposed alignment of the tube-tunnel will almost coincide with the critical section at the southern entrance. Therefore, significant effects on the flow system in the Bosphorus — most probably on the blocking phenomena — are expected due to the reduction in the cross-section. Considering the strong interrelations between the hydrodynamic features of the Bosphorus and the tube-tunnel crossing which in turn may affect the performance of the marine outfall systems, owners of these projects jointly

*ISOPE Member.
Received January 17, 1994: revised manuscript received by the editors November 30, 1994. The original version (prior to the final revised manuscript) was presented at the Fourth International Offshore and Polar Engineering Conference (ISOPE-94), Osaka, Japan, April 10-15, 1994.
KEY WORDS: The Bosphorus, two-layer flow, oceanographic measurements, tube-tunnel.