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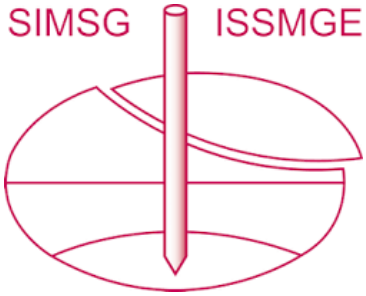

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Settlement of Buildings in Istanbul

Études sur les tassements des bâtiments anciens à Istanbul

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Summary

The author reviews a research on the settlements of existing structures on the shores of the Golden Horn. An old fountain built in 1810 has settled more than 180 cm with a differencial settlement of 57 cm ; its recalculated settlement is 115 cm.

The investigations made on this and many other structures in the same area have shown that the shores of the Golden Horn seem to move towards the sea under their own weight.

A group of buildings of the power station of Istanbul built on the north end of the Golden Horn between 1915-1956 has settled from 8 to 99 cm.

Recalculation of settlements has shown that geological details and other geotechnical properties have considerable influence on settlement forecasts.

Sommaire

Cette communication résume une étude sur les tassements des bâtiments anciens construits sur les rives de la Corne d'Or.

Une fontaine ancienne construite en 1810 a subi un tassement de plus de 180 cm et le tassement relatif est de 57 cm. Le tassement moyen calculé est de 115 cm.

Les études faites sur cette fontaine et sur plusieurs autres ouvrages ont démontré que les rives de la Corne d'Or semblent être en mouvement vers la mer, même sous leur poids propre.

Un groupe de bâtiments de l'usine d'électricité d'Istanbul construit à l'extrémité nord de la Corne d'Or entre 1915 et 1956 a subi des tassements allant de 8 à 99 cm.

Les calculs démontrent que les propriétés géologique et géotechnique, en plus de la compressibilité, ont une influence considérable sur les tassements prévus.

Power Station of Istanbul

The power station occupies an area to the north end of the Golden Horn (Fig. 1 and 5). Geological sections and the locations of the turbine and boiler houses are shown in Fig. 2. Settlement records of the four buildings are given in Fig. 3. Foundation systems, dimensions, average soil pressures and observed settlements in 1957 are summarized in the following table :

Structure	*Foundation* m²	σ_0 t/m²	*max and min settlements in* 1957 cm	*Date of construction*	*Remarks*
Turbine house I No. 39	Raft 55 × 27 1 m thick	4·37 (1915) 5·35 (1918)	46 97	1915	6 m sheet piling under mach. foundations
Turbine house II No. 40	Raft 27 × 23 0·7 m thick	4·5	47 62	1921	7 m R.C. Piles in groups under mach. Found.
Boiler house I No. 34	Raft 37 × 27 1 m thick	4·37	90 62	1915	—
Boiler house II No. 33	37 × 26	7·65	99 79	1929	—
Boiler house III No. III	31 × 32	5·5	60 53	1939	Raft is of box type
Boiler house IV No. 32	41 × 56	4·5	8 21	1955	—

No settlement measurements were made inside the buildings, but severe trouble was caused by excessive settlement. Buckled trusses, deformed crane tracks, tilted and cracked machine foundations have been kept under continuous repair.

Site exploration has been carried out for a new boiler house in place of building No. 33. On the area nine boreholes have been carried out, and 7 cm diameter tube samples have been taken and tested.

The location of eight boreholes are given in Fig. 2. Laboratory test results are summarized in Fig. 4.

Foundation soil consists of alternate strata of organic clayey silts and silty layers containing macroscopic and microscopic partly decayed vegetable fragments, and shells. Layers are cut by water-bearing thin seams. The surface of the bed-rock, mostly Devonian shales, is shattered and weathered. Water in cracks and seams is of artesian character and rises to the ground level. Soils layers contain

gaseous products of decayed substances. In borehole No. 9 (not shown in the figure) a sand layer between 40·5 and 45·6 m depth contained methane gas under such a pressure that the boring rods auger and sand were shot out of the hole up to a height of about 10 m. The borehole gave out gas for weeks, which was burned.

In some boreholes silty soils rose up to 1·0 m during the night interval and boreholes had to be filled with water to prevent boiling.

Settlements of buildings Nos. 33 and 37 have been re-calculated. The results are summarized in the following table :

Building No.	*Calculated settlements*		*Measured settlements*		max τ kg/cm²	*Average* s kg/cm²	*Assumed rigidity*
	Centre cm	*Corner* cm	*in* 1957 cm	*final* (+) cm			
33	101	47 to 51	79 to 99	85 to 101	0·22	0·25	*Flexible*
37	70	70	53 to 59	80 to 85	0·18	0·25	Rigide

* Extrapolated.

Fig. 1 Location of the site.
Emplacement de l'usine.

In these calculations adjusted K lines for (e — log p) curves were used to determine the modulus of compressibility. To estimate the final observed settlement extrapolations have been made. To that end the trend of the time-settlement curves of the buildings Nos. 34 and 39 were taken as a basis. According to these curves 90 per cent of the consolidation is reached in about 20 years. Settlements due to secondary time effect is about 0·5 to 1·0 centimetre per year.

Maximum shear stresses under the building No. 34 is very near to the average shear strength of the soil. This fact seems to be the main reason for the difference between calculated and observed settlements.

Old fountain at Unkapani

This structure was built by Kapani Ahmed Aga in 1810 at Unkapani on the shore of Golden Horn. The ground near this structure has been filled many years ago. For a new project of a storehouse soil investigations have been made, and samples taken from 11 borings have been tested. Geological sections, the topography of the bed-rock, geotechnical properties of the soil layers are given in Fig. 5.

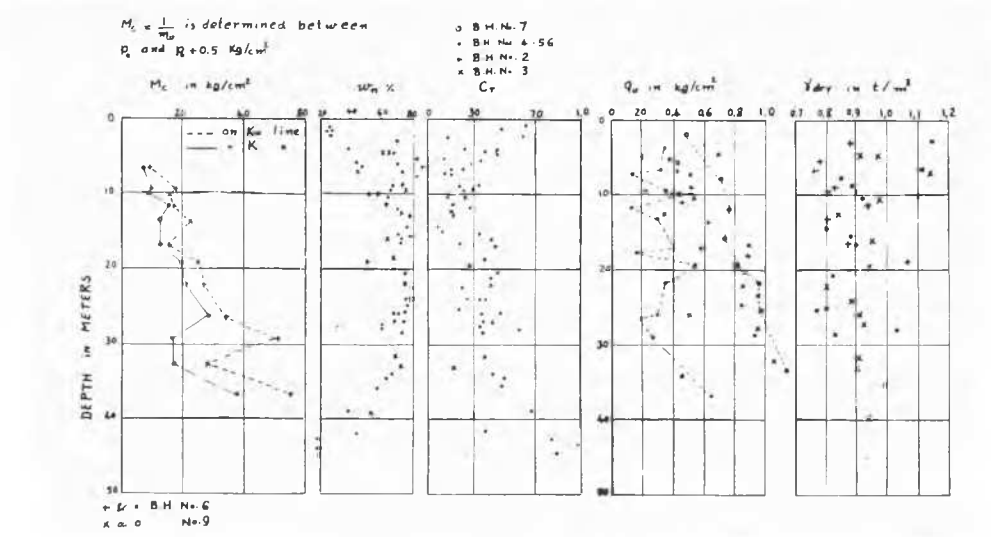

Fig. 4 Geotechnical profiles (E.T.T.).
Profils géotechniques (E.T.T.).

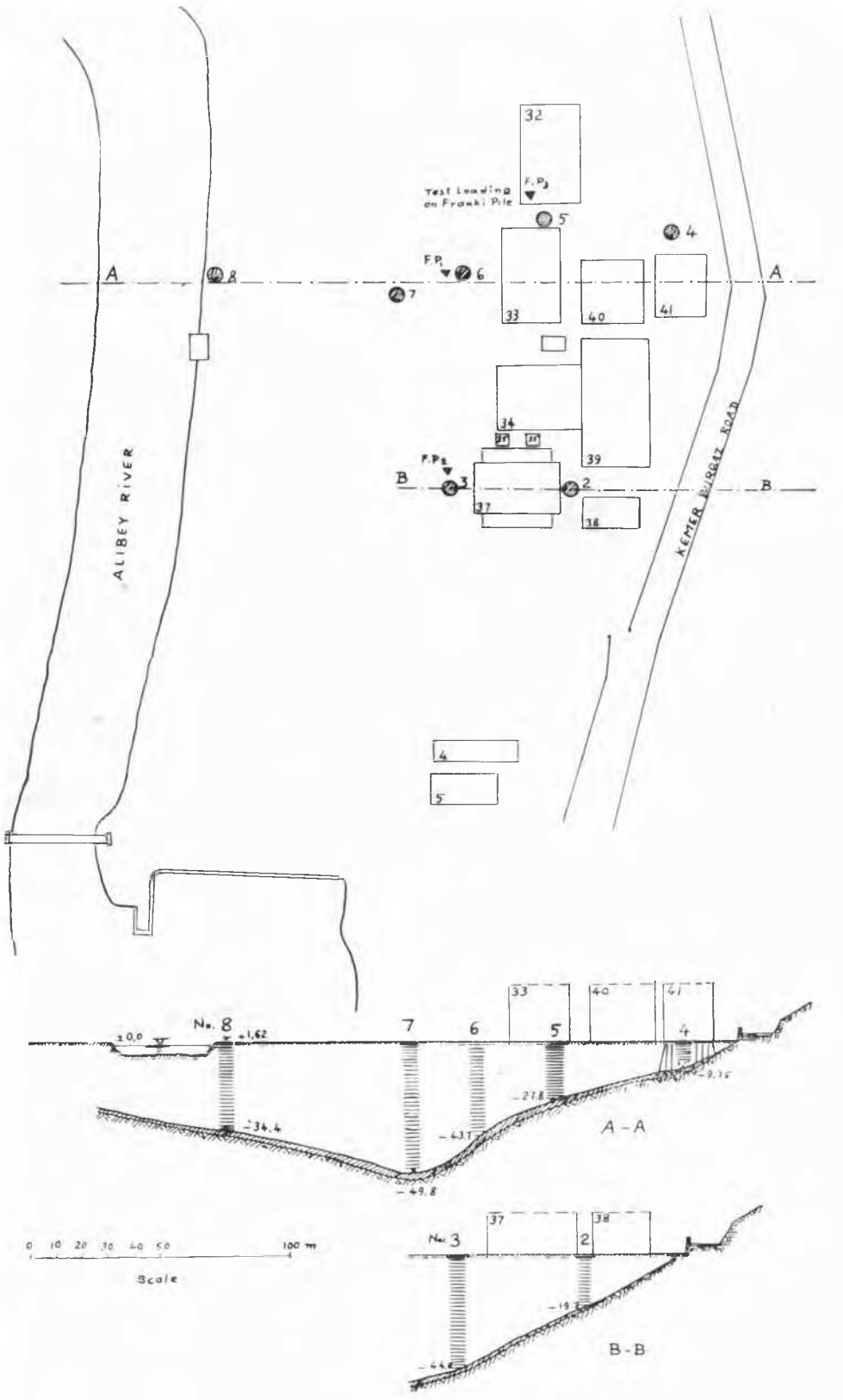

Fig. 2 Location of the buildings and geological sections.
Emplacement des bâtiments et coupes géologiques.

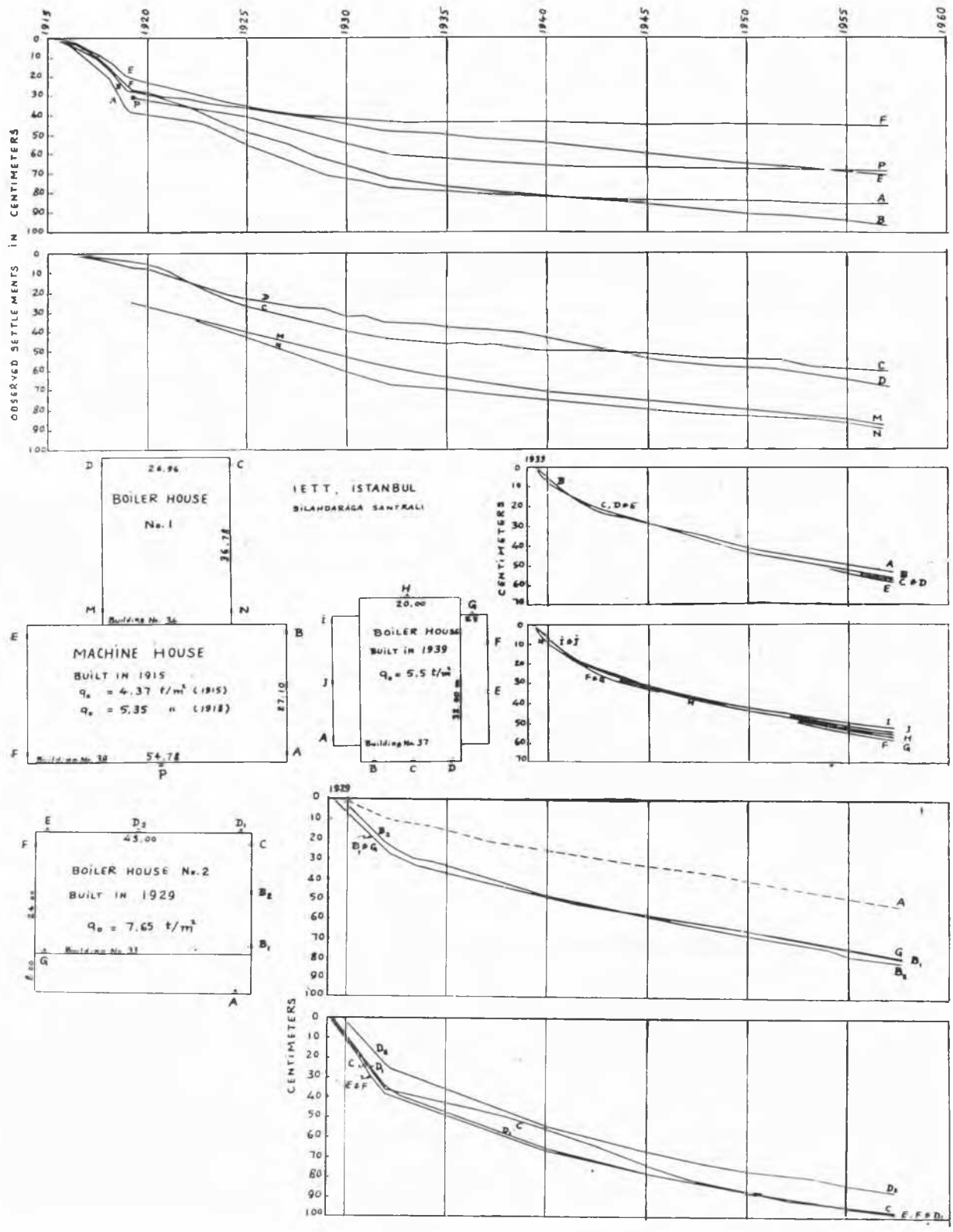

Fig. 3 Observed time, settlement curves.
Diagramme des tassements observés en fonction du temps.

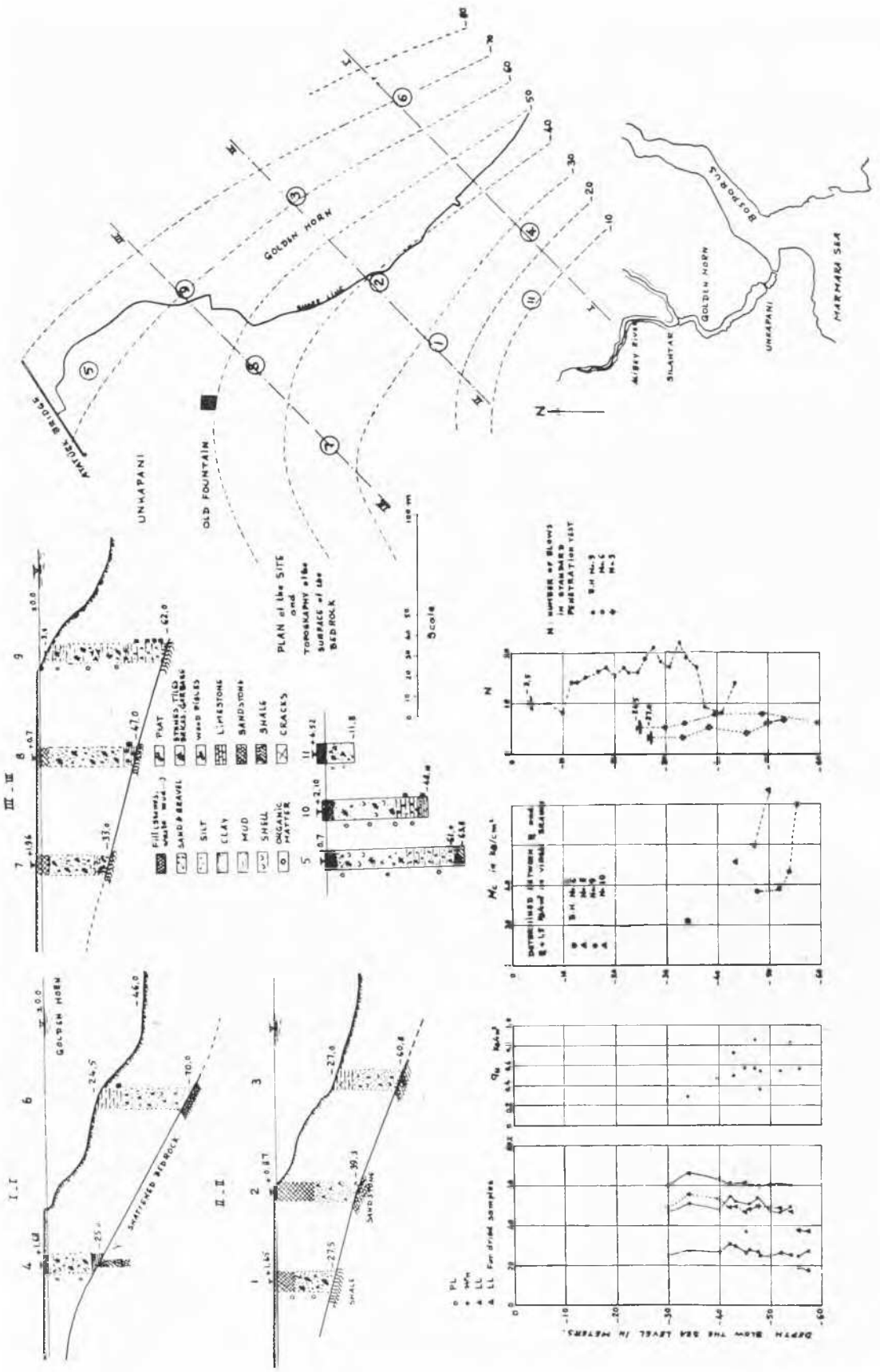

Fig. 5 Plan of the site, geological and geotechnical profiles (Fountain).
Plan de l'emplacement, profils géologiques et géotechniques (Fontaine).

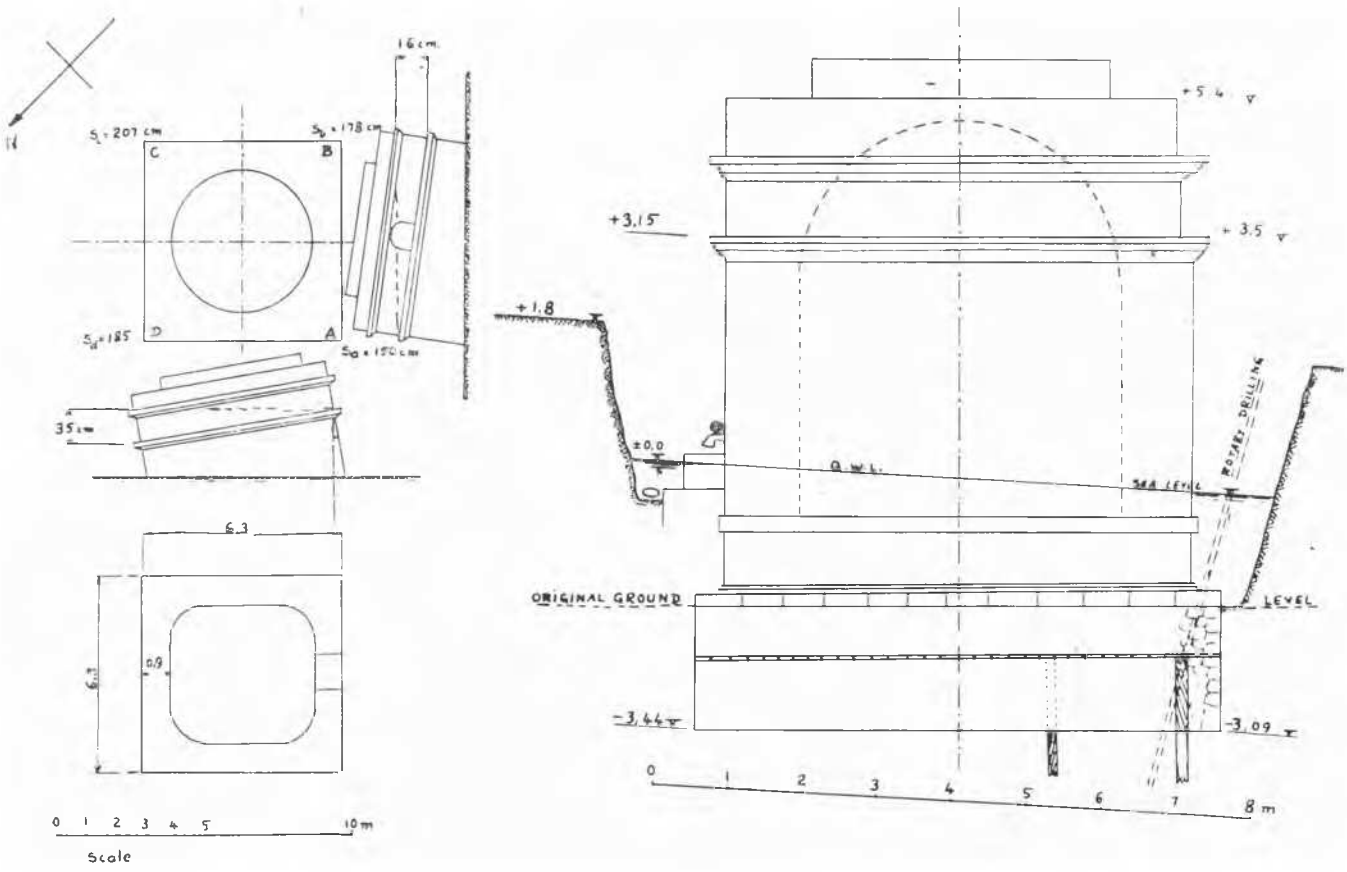

Fig. 6 Present state of the old fountain.
Etat actuel de l'ancienne fontaine.

Fig. 7 Old fountain.
L'ancienne fontaine.

Down to a considerable depth the soil consists of clayey silts containing city refuse, organic matters, stones, shells, remnent of old foundations. For these layers laboratory tests are not suitable to determine mechanical properties.

The state of the fountain is shown in Figs. 6 and 7. Average settlement of this rigid block is about 180 cm and the differential settlements of the corners are 28-35 and 57 cm.

Calculated final settlement is 115 cm. Of this value 71 cm is due to the fill, and 44 cm to the structure *.

In this case the difference between calculated and observed settlements and excessive differential settlements seems to be a result of the soil movements towards the sea. In fact, the shape of the under-water slopes, the possibility of a temporary liquefaction of the deeper silty fine sands during the earthquake shocks, the steepness of the bed-rock, and deformation of the buildings in the vicinity as shown in Figs. 8 and 9 provide the evidence for such movements.

* For settlement calculations results of a test loading on a similar soil were also used.

Fig. 8 show a sketch plan of Yemis area, about 400 m eastwards from the fountain, and the buildings which settled and tilted excessively. Section C-C gives a probable mechanism of the slide of the Hilal Han in 1952. Failure occured suddenly in the evening. There were no casualties. The local inhabitants reported that the building lies upside down on the bottom of the sea. The author was told that he space behind the Ataman Han (D-D) had been widened since its construction. Fig. 9 (a, b, c, d) are photographs of the buildings marked in Fig. 8.

Acknowledgement

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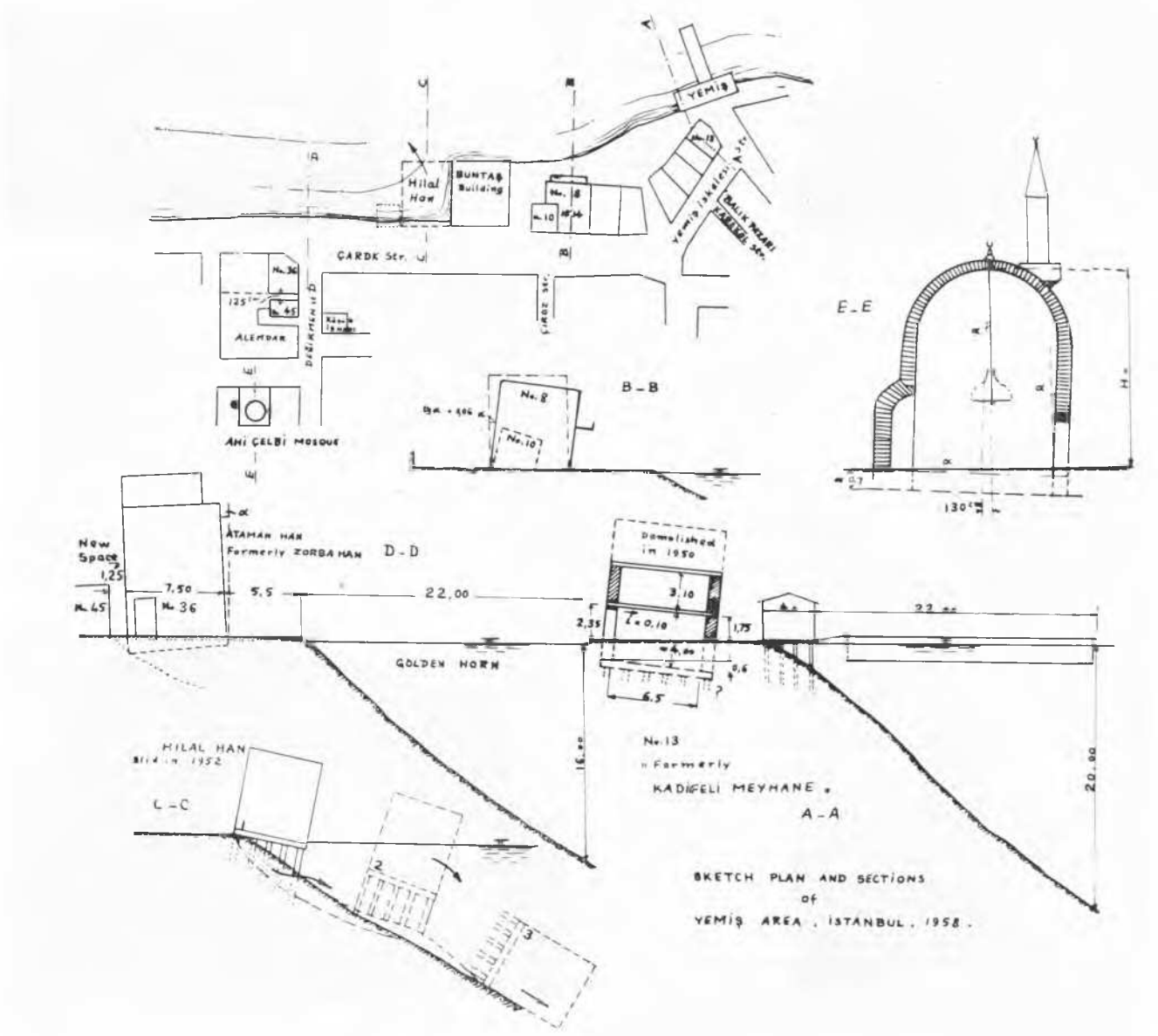

Fig. 8 Sketch plan of the Yemis area.
Plan de la région Yemis.

A

B.

C.

D.

Fig. 9 (a) Building on section D-D ; (b) Building on section B-B ; (c) Building on section A-A ; (d) Building on section C-C.
(a) Bâtiment sur la section D-D ; (b) Bâtiment sur la section B-B ; (c) Bâtiment sur la section A-A ; (d) Bâtiment sur la section C-C.