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No. I-4

PILE DRIVING AND TEST LOADING RECORDS

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Scope. The following contribution contains information regarding the local soil, and data obtained from various pile driving records and loading tests which have been either supervised or observed by one or both of the authors.

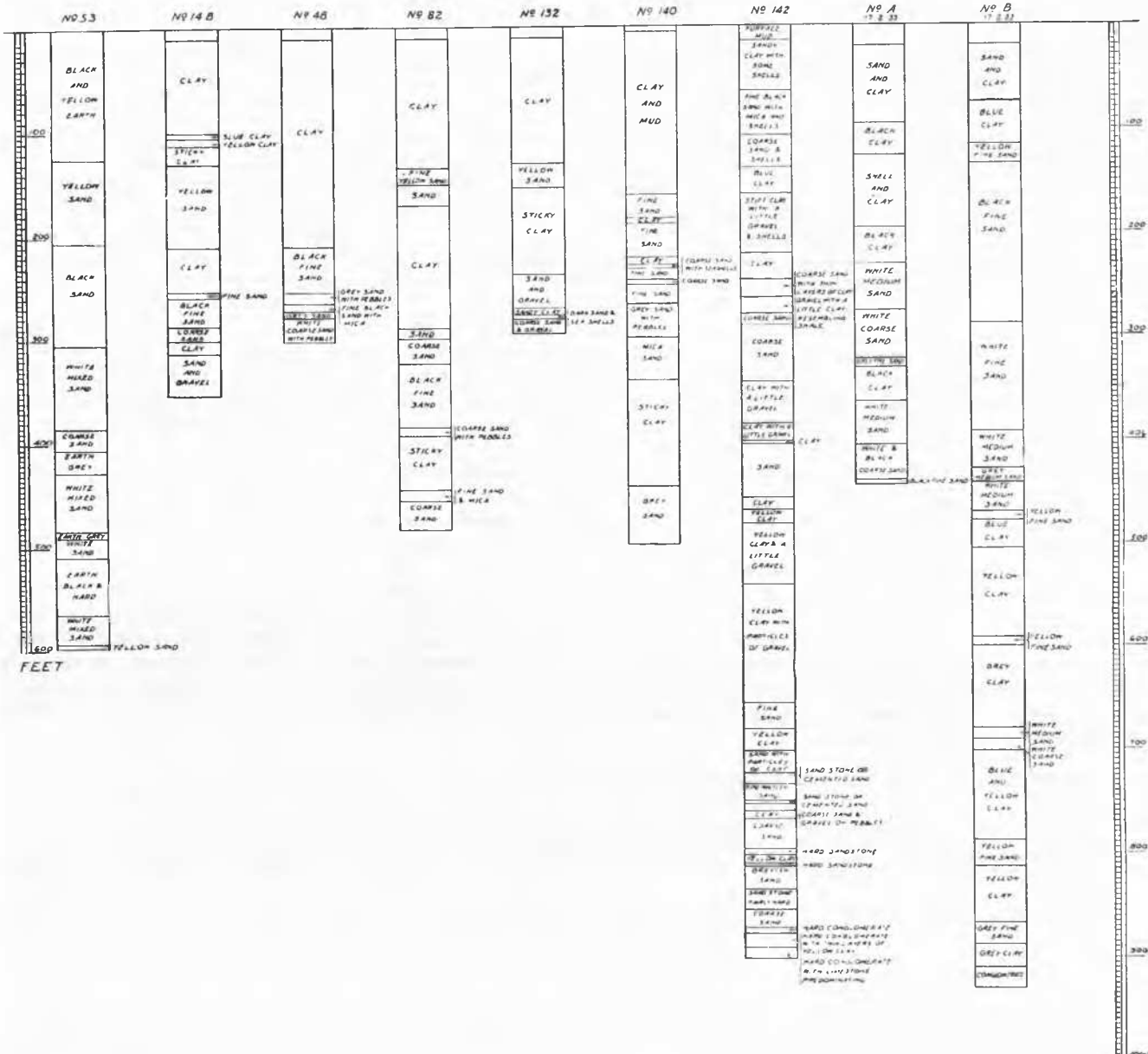
The Local Soil. Detailed information regarding the composition and stratification of the Shanghai mud is contained in several papers which have been read before the Engineering Society of China by Dr. Herbert Chatley and others, and in the publications of the Whangpoo Conservancy Board. (See Bibliography submitted by The Engineering Society of China.) Dr. Chatley's general description as follows may form a guide:-

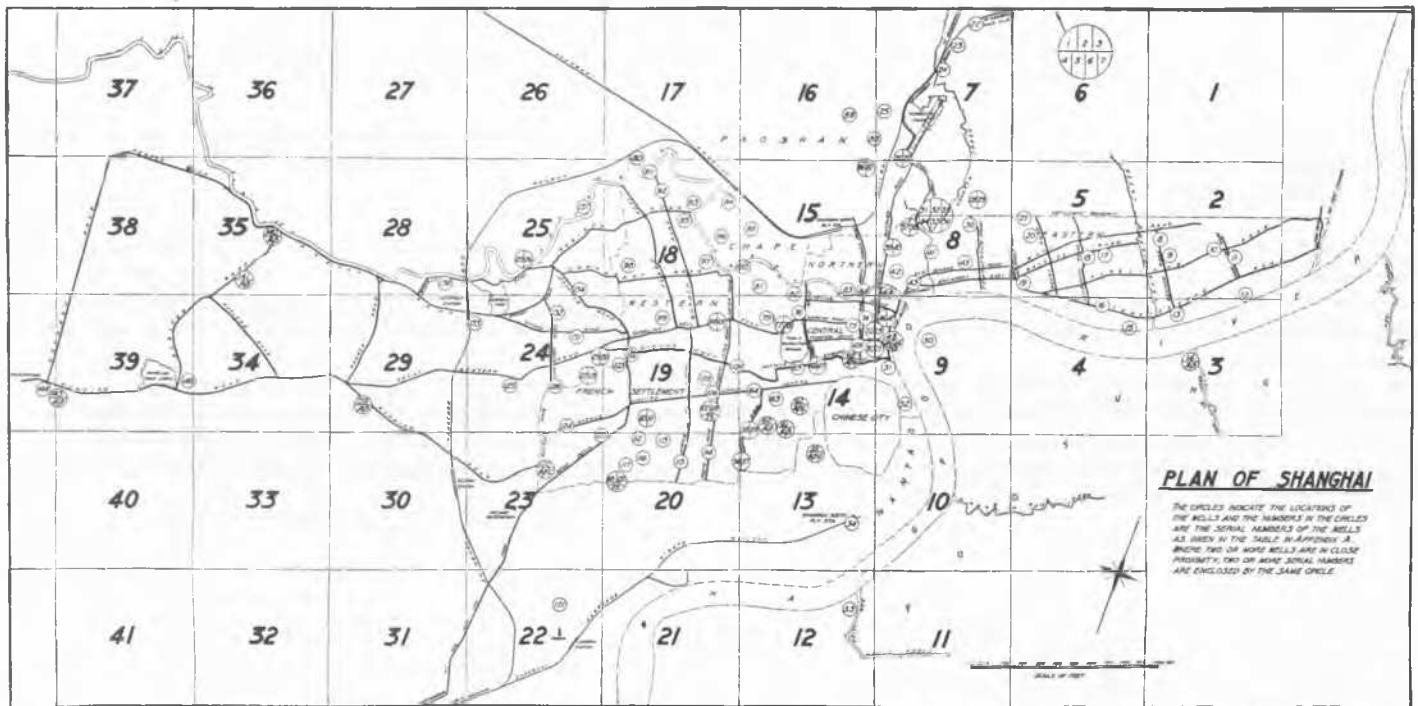
(a) **Physical Properties (Surface material).** Material a consolidated silt, wet density about 1.75; grain density 2.75; about 80% of the particles pass a 200 mesh per inch screen; minerals, aluminosilicates; about 10% colloids; moist shearing strength about 300 pounds per square foot. Waterlogged below mean tide water level, say six feet below ground (See Shanghai Harbour Investigation Report, Series 1, No. 7, II-III, Whangpoo Conservancy Board 1921).

SHANGHAI DEEP WELL BORINGS

APPENDIX C.

THESE TWO BORINGS ARE ONLY 30 FEET APART





PROCEEDINGS ENGINEERING SOCIETY OF CHINA Vol. XXX 1930-31, 32-33

APPENDIX D

F. G. C. WALKER, F.I.C., PH. C. DEEP WELL WATERS IN THE SHANGHAI AREA.

(b) General Geological Conditions. Alluvium of Yangtze delta, consisting of siliceous and argillaceous material eroded from Red Basin in Szechuen, quartz from various riparian outcrops in Yangtze, disintegrated porphyrite from local outcrops, small proportion of secondary loess from Shensi windborne to Northern Anhwei and thence via Hwai river to Yangtze. Alluvial beds to about 900 feet below Shanghai; porphyrite hills 15 to 100 miles away in various directions. Marine sands at varying depth below 100 feet or surface silt (See Shanghai Harbour Investigation Report, Series 7, Sect. I, Whangpoo Conservancy Board 1921; also report and map by Geological Survey of China (Peiping), on geology of Kiangsu province; also F. G. C. Walker's paper to Engineering Society. ("Deep Well Waters in Shanghai", Proceedings, The Engineering Society of China, Vols. XXV & XXXI.) The main point, so far as these records are concerned, is that no rock or coarse gravel has yet been located at a lesser depth than about 700 feet below the surface in the area concerned. The logs of well borings contained in F. G. C. Walker's paper are reproduced herein and they show the general nature of the deposits above the 900 foot level. Most of these were wash borings and the depths of individual deposits should be regarded as approximate only. As regards uniformity of the strata Mr. Walker says, "It is a fact that waters from the same approximate level at different parts of the area can show entirely different chemical character which suggests a lack of uniformity." Shanghai formerly consisted of a network of creeks and ponds, the bends of which were usually not more than 12 feet below ground level, since filled, sometimes with refuse. This is a source of serious variation in "strength" in shallow foundations.

The nearest approach to an undisturbed sample ever examined was obtained in the center of the city by driving two steel channels one enclosing the other to a depth of 140 feet and then extracting them simultaneously, so bringing up an intact core which was exposed for examination by removing the larger channel. This sample showed no violent change in the mud but indicated a marked change in hardness at a level 60 feet below the surface where a definite horizon occurred marked by a thin band (about 1") of sand and shells. The following penetrations were obtained with a B. S. Vicat plunger on the fresh sample. They do not appear to support the manual tests as regards hardness at 60 feet, but do indicate a hard layer at 95-115 feet.

Depth below Road level	45'	55'	65'	75'	85'	95'	105'	115'	125'	135'	140'
Penetration of needle cms	3.67	3.604	3.74	3.764	3.724	0.18	0.09	0.14	2.655	3.08	2.90

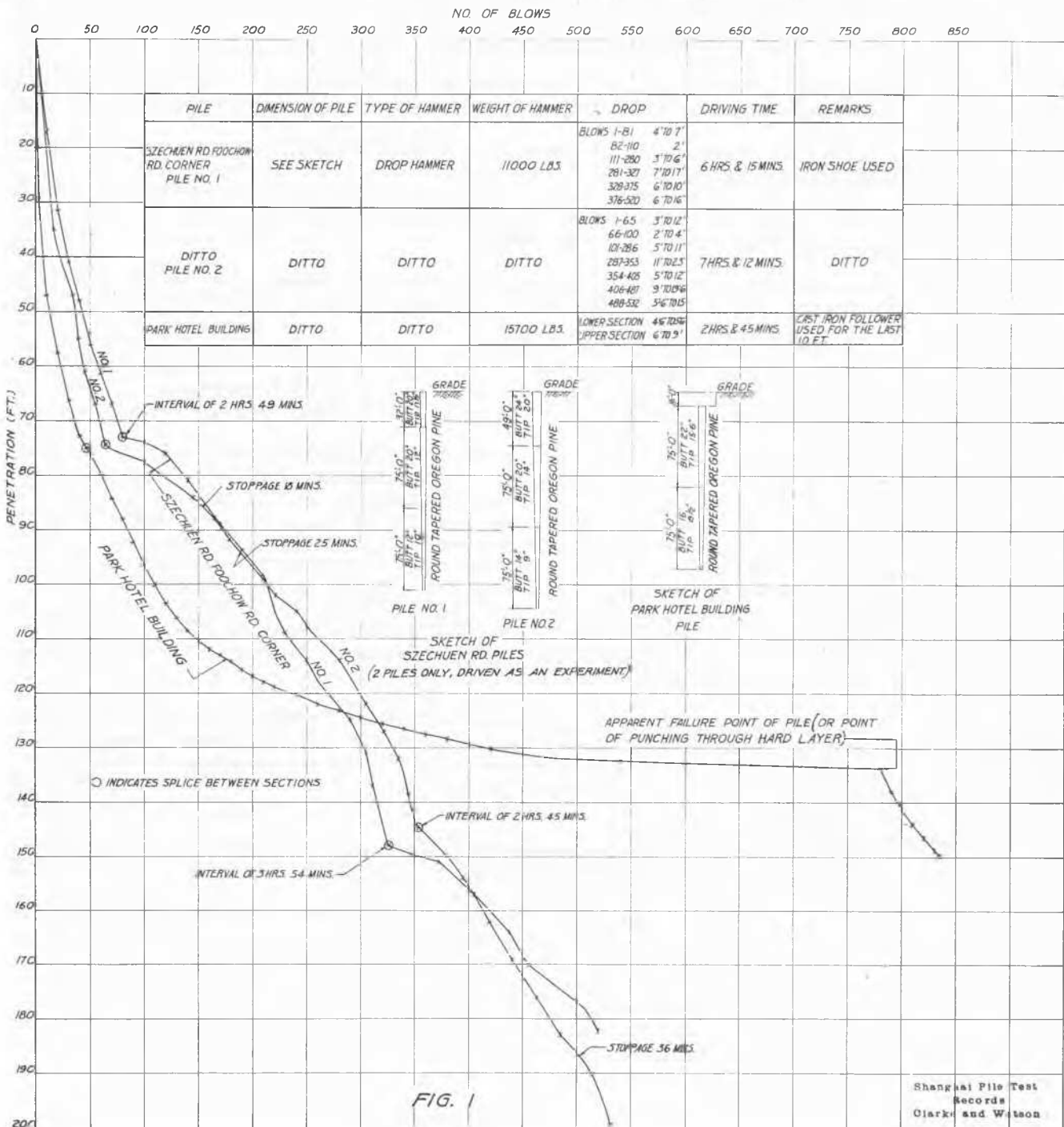
The Vicat plunger used was 10 mm dia as described in B.S.S. No. 12, 1931, for Portland cement, the total imposed weight including the plunger and all attachments being 300 grams.

The soil varies in resistance to pile penetration at different depths, and in different parts of Shanghai. At commencement of driving, an initial penetration up to 30 feet often occurs under the static weight of the hammer, no impact being applied. Piles do not usually refuse but one site (Park Hotel. See Fig. 1) is known where the piles were driven almost to refusal when their tips reached a depth of about 140 feet below ground level, whilst on another site the refusal depth was about 65 feet. On the other hand, jointed timber piles 190 feet long have been driven without great difficulty on another site, as is shown by the penetration record given in Fig. 1.

TABLE 1

SUMMARIZED DRIVING RECORDS
(SEE ALSO SEPARATE CONTRIBUTION 4)

BUILDING	AVERAGE PENETRATION FOR LAST 10 BLOWS (INCHES PER BLOW)	AVERAGE TOTAL NUMBER OF BLOWS PER PILE	AVERAGE DROP (INCHES)	WEIGHT OF HAMMER (LBS.)	TYPE OF HAMMER	AVERAGE LENGTH OF PILE P (FT.)	MEAN DIAMETER OF PILE INCHES	REMARKS
VICTORIA NURSES HOME	10	22	42 & 72	9850	DROP	53	10 1/2	AVERAGE DROP FOR LAST 10 BLOWS WAS 42" & AVERAGE DROP FOR PREVIOUS BLOWS WAS 72"
CARTER ROAD POLICE QUARTERS	6 1/4	54	72	8960	DROP	60	11	
INDIAN WARDERS QUARTERS	LESS THAN 5	—	72	8960	DROP	60	11	AVERAGE PENETRATION FOR LAST 8 FEET WAS 5 1/2 INCHES PER BLOW
JUVENILE BLOCK	5 3/4	51	60	7840	DROP	45	10	
CELL BLOCK R.S.	5 1/4	55	60	7840	DROP	44	10	
POLICE HOSPITAL	—	80	60	4480	DROP	40	12	
GAOL HOSPITAL	—	78	60	4480	DROP	38	10	
ADMINISTRATION BLOCK	—	68	60	6720	DROP	60	12	
WEST SICHOW ROAD FIRE STATION	1 1/3	175	72	8960	DROP	70	13 1/2	Shanghai Pile Test Records Clarke and Watson



No satisfactory local formula for the safe bearing capacity of piles in groups has yet been devised. The results of single pile loading tests are merely an indication of the relative value of the pile type or the ground. Local buildings usually continue to settle over many years. One building without piles constructed in 1914-16 is known to be still moving.

Darkly stained water or sap has frequently been observed oozing from the butts of piles after driving indicating upward drainage through the pile. This, to some extent, relieves the internal pressures in the soil set up by the driving of the piles. But that there is also plastic flow of the soil is evident from (1) observed movements of bridge piers on driving and extracting falsework piles, (2) the rise of piles, already driven, when driving adjacent piles, (3) the rise of mud over a heavily piled site, especially inside steel cofferdams, (4) the observed disconcerting rise and fall of permanent bench marks, and (5) the distortion of roads and compounds in the vicinity of heavy buildings. The so-called "elastic recovery" of test piles when off-loaded is more probably reverse plastic flow as on removing a load before the "restraint" of the surrounding soil is dissipated the pressure gradient is reversed. Such recovery after protracted loading in the authors' experience does not occur. Slow drainage and resulting compaction of the disturbed soil under a piled foundation undoubtedly occur, so that some settlement seems inevitable.

Patches of fine quicksand have been found sporadically down to 25-30 feet below the surface. This material will flow under the tips of sheet piling into excavations.

The mud liquefies readily when vibrated and closes in very rapidly when a pile or dolly is withdrawn.

All trenches deeper than four feet must be sheet piled and infiltration of water into excavations is generally slight but continuous. Sub-floor relief drains are necessary in basement work during construction.

Road foundations other than concrete even in localities free from heavy loads are troublesome probably owing to upward capillary flow of groundwater.

Sewer and drain pipes of concrete or earthenware with rigid joints must be provided with continuous reinforced concrete slab foundations, failing which serious movement and breakage occur.

The ground is completely waterlogged in the wet season.

File Driving Records. Penetration curves and other relevant data for various piles driven in different parts of Shanghai are given in Fig. 1 and 2. The two experimental piles 199 feet and 182 feet long respectively (each in separate lengths spliced together) driven by Mr. L. E. Hudee, are believed to be the longest piles ever driven in Shanghai. (See Fig. 1.) The record given in Fig. 1 for the Park Hotel building is also for a similar Oregon pine pile driven by Mr. Corrit in two lengths spliced together by means of a steel cylinder. Several such piles were driven almost to refusal, and the one recorded appears to have broken, (or, a remote possibility, to have suddenly punched through a specially resistant layer).

Table I gives a summary of driving data for piles under certain Municipal buildings of which the settlement records are given in a separate contribution. ("Settlement Records and Loading Data for various buildings erected by the P. W. D., Municipal Council, Shanghai.") File driving records have been found useful only as a qualitative indication of the capacity of the upper soil layers in different sites. Bearing capacity has not yet been successfully related to driving data in this soil.

All the piles were driven vertically by means of an ordinary drop hammer moving between timber guides, released by means of a monkey trigger. The head of the pile was protected from "brooming" by means of a stout steel driving ring or helmet, sometimes surmounted by a wad of packing of empty gunny sacks, coarse native paper, or native straw-boarding. In most examples cited, the piles were driven prior to excavation, the last five to ten feet of driving being effected by means of a timber dolly retained in position on the pile head by a steel spike.

Bearing Capacity. As an indication of the bearing capacity of the soil within about four feet of the surface, an old rule for plain footings is "The pressure of foundations on the natural ground shall not exceed 1,700 pounds per square foot." (See also Appendix 2 for a recent amendment to this rule.) The bearing capacity at depths of 30 feet and 50 feet are indicated approximately by the results of a test carried out by Messrs. Braithwaite & Co., Ltd. (Mr. G. Wilson, B.Sc., A.M.Inst.C.E.) on a screw pile during 1932 which was observed by the authors.

The pile used consisted of a mild steel rivetted tube 3'-2 $\frac{1}{2}$ " external diameter and $\frac{1}{4}$ " thick, having a helical screw blade attached to its base, 5'-8" overall diameter consisting of one turn of 10 $\frac{1}{2}$ inches pitch.

The pile was first screwed down to a depth of 30 feet below ground level, and then gradually loaded over a period of 19 $\frac{1}{2}$ days, at an average loading rate of 4.87 tons per day up to 95 tons (including weight of pile and loading platform), the total settlement being then three inches. This load was maintained constant for a period of 10 days without appreciable increase in settlement. The bearing pressure at this load, assuming the bottom of the tube solid, and ignoring possible skin frictional resistance, and the weight of soil above the projecting screw-blade, was 8,500 pounds per square foot. The base of the tube was kept open throughout. The gross load was then gradually increased to 105 tons and at this point settlement continued without increase in load. See Fig. 3 and 4.

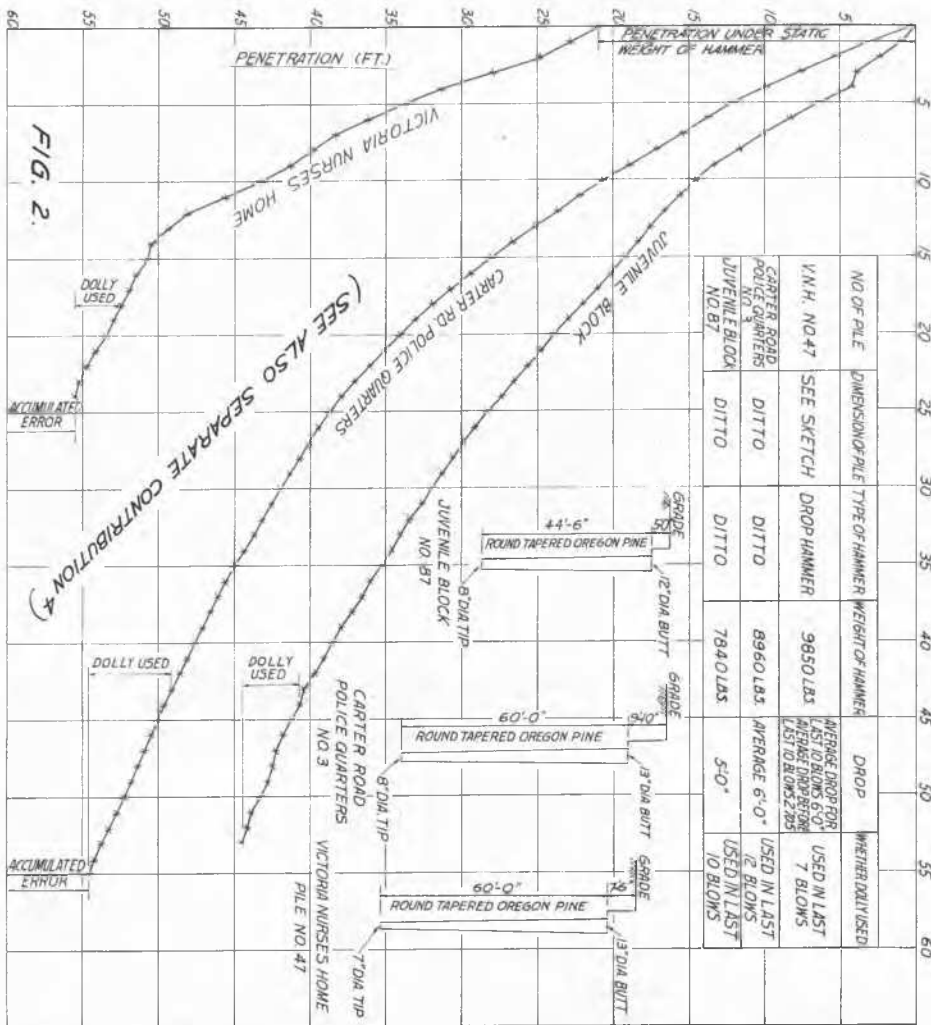


FIG. 2.

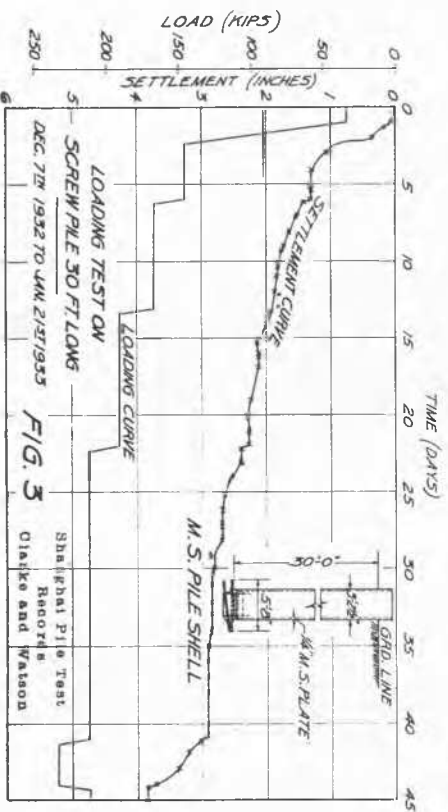


FIG. 3

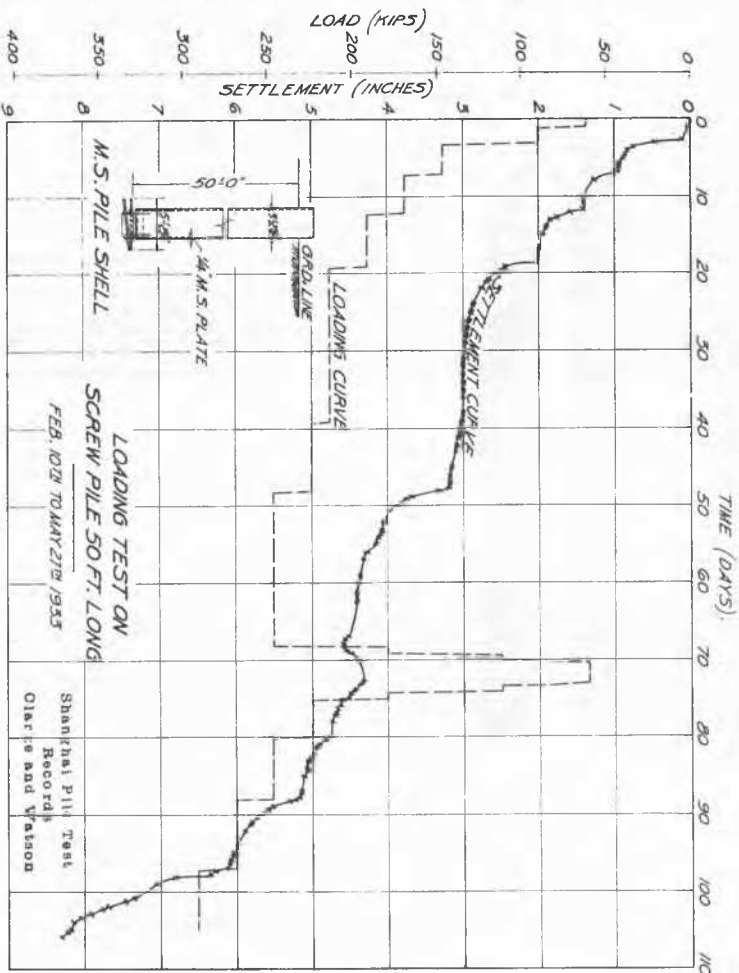


FIG. 4

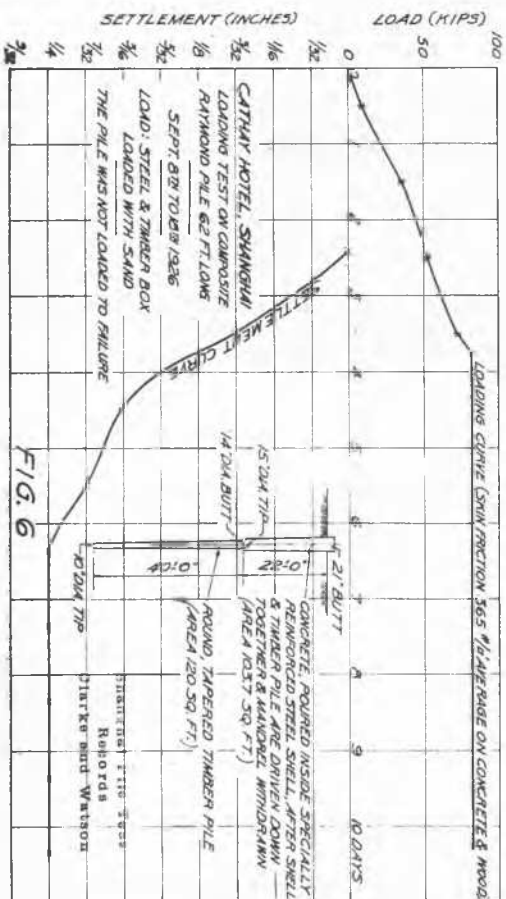


FIG. 6

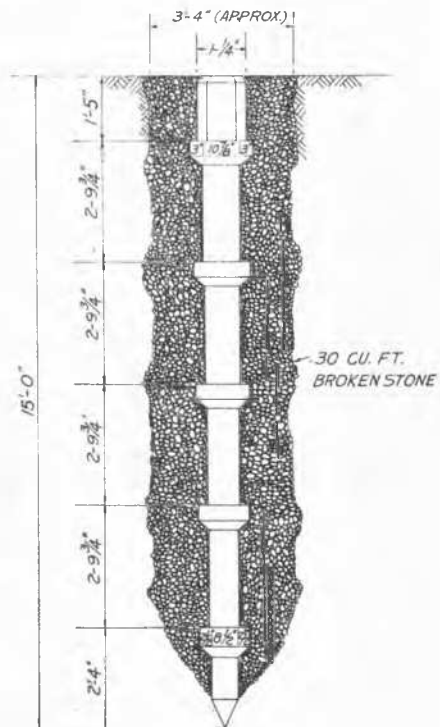
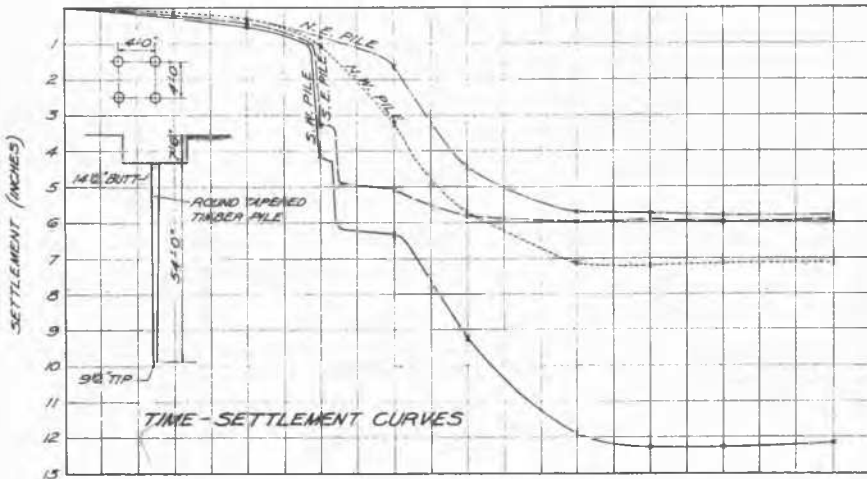
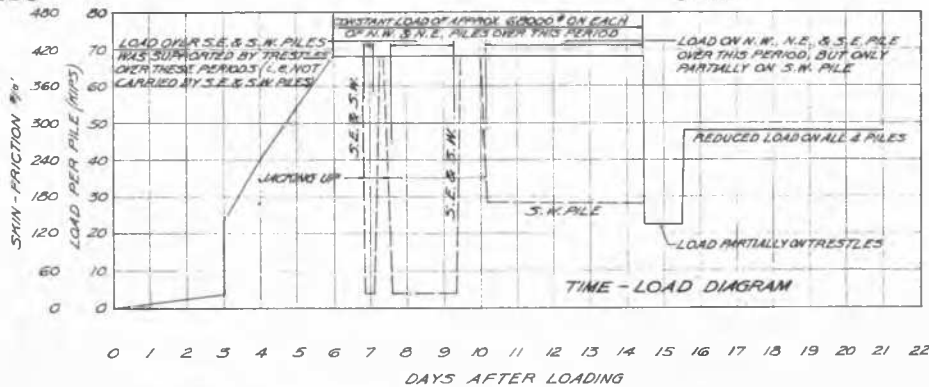
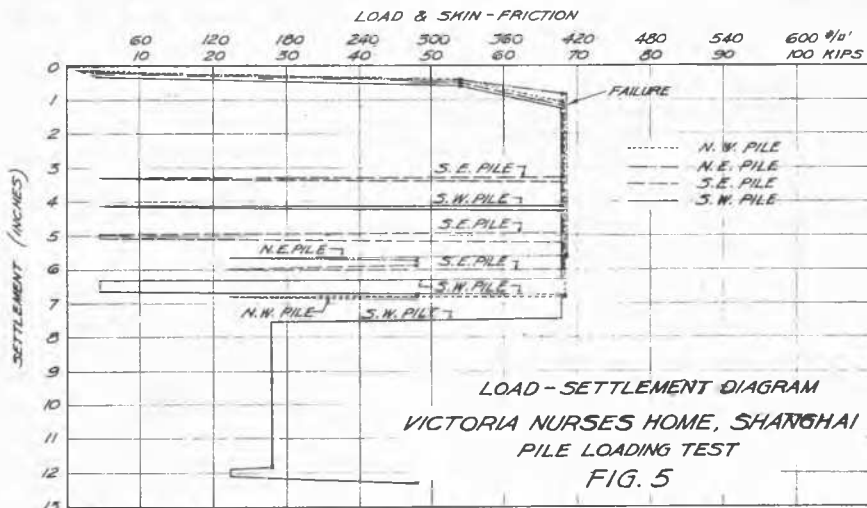
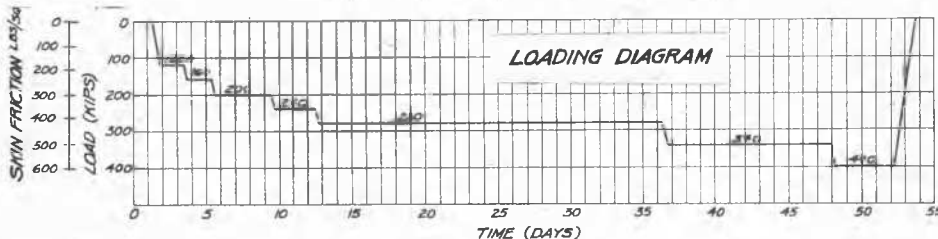


FIG. 6

DETAIL OF 15 FT. STANDARD TAKECHI R. C. PILE



LOAD-SETTLEMENT DIAGRAM
VICTORIA NURSES HOME, SHANGHAI
PILE LOADING TEST
FIG. 5

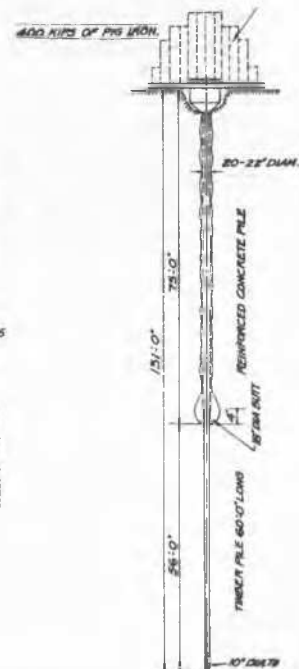


SURFACE AREA OF PILE
CONCRETE PILE = 4.35"
ENLARGED BASE = 15"
TIMBER PILE = 210"
TOTAL SURFACE AREA = 660"

LOADING TEST ON SVAGR PILE

MAY 22ND TO JULY 14TH 1933

FIG. 7.



The same pile was then screwed down to a depth of 50 feet below ground level, and the bottom of the tube plugged with concrete. Load was then added gradually up to a total of 110 tons, when a timber under the platform crushed, the settlement being $4\frac{1}{2}$ inches. On removal of the load the pile rose 0.24 inch. The load was then re-applied until at 130 tons a total settlement of 8.35 inches was observed. The test was then abandoned.

File Loading Tests. Loading tests which have been carried out in Shanghai from time to time, mostly on isolated piles, have shown the failure skin friction stress to vary from 400 pounds per square foot to 500 pounds per square foot, or more, for round tapered Oregon pine piles of from 40 to 60 feet long, though higher figures have been obtained from other types of pile. The lowest results so far obtained by the P.W.D. for piles of fair length are given in Fig. 5. A group of four piles was loaded with broken stone, contained in a timber box supported on steel beams, carried by four screw-jacks, one on the head of each pile. By means of these jacks it was possible to counteract the unequal settlement of the piles and keep the box vertical and clear of the guard trestles as the piles settled.

Test on a Composite Raymond File. This test was carried out by Messrs. The Hongkong Excavation, Pile Driving, and Construction Co., Ltd. and observed by the P.W.D. The results are given in Fig. 6. On three consecutive days during the test, the sand became soaked owing to heavy rainfall. The extra load due to this cause, has not been taken into consideration in the loading diagram.

Svagr File Test. This composite pile was driven and tested by Messrs. The Svagr Bros. Foundation Co., the authors witnessing the driving and checking the observations. The results are given in Fig. 7 together with a detail of the pile. The Svagr patent composite pile presents a novel principle in that a timber pile is driven down within a previously driven steel tube by means of a follower consisting of another steel tube of smaller diameter, until the butt of the timber pile is nearly down to the level of the base of the larger tube. Concrete is then poured down the larger tube and rammed by means of the inner tube until it forms a "bulb" enveloping the butt of the timber pile. Reinforcement is then placed in the larger tube and concrete is alternately poured and rammed, the ramming being carried out by means of the inner tube, both tubes being simultaneously and gradually withdrawn. The load was gradually applied over a period of 8 weeks. The maximum load reached was 400,000 pounds corresponding to a skin friction stress of approximately 600 pounds per square foot, at which load the test was terminated before the pile had come to rest. The pile head rose about $1/5$ of an inch on removal of the load.

Takechi Pile Test. A "Takochi" pile 15 feet long of reinforced concrete, see Fig. 8, was driven and loaded under the authors' observation, by Mr. Shojiro Takechi, civil engineer of Osaka. 30 cubic feet of broken stone were forced into the ground surrounding the pile, by the pile itself, during driving. (The Takechi pile has been successfully used in the foundation of a large cotton mill in Shanghai.) The pile was loaded up to 75,400 pounds (consisting of a timber box filled with loose broken stone) not including the weight of the pile. The settlement remained constant at 0.297 inch for 10 days under this load. The load was then removed.

Additional Information. Further notes on Foundations on Shanghai Soil are contained in a paper by Mr. S. E. Faber read before the Local Association of the Institution of Civil Engineers in 1932.

Acknowledgements. The authors are indebted to the Commissioner of Public Works, Shanghai Municipal Council, for permission to publish the records and data contained herein, and to members of the staff for their assistance in preparing tables and curves.

No. I-5

LOAD TEST ON A WOOD PILE DRIVEN INTO THE GROUND

Dr. R. Tillmann, Oe.I.A.V., Building Department of the Municipality of Vienna

In the autumn of 1929, a foundation layer was dumped at the mouth of the River Wien and the Danube Canal on a then existing stretch of land and secured on the water side by a pile work of larch-wood and banked up with a quarry stone pavement embedded in mortar. The former consists of a 180 m wall of round piles 4.5 m to 5 m in length placed side by side and earth anchorages spaced 5 m apart. The piles are about 30 cm in diameter and provided with steel shoes. Pile driving was done by means of a motor-driven rammer with a 600 kg drop hammer, the mean drop being about 3 metres. During these operations, a pile load test was carried out for scientific interest. Its arrangement will be seen from Fig. 1. One group of the eight piles 1 to 4 and 6 to 9 was fixed together by means of band steel loops along an I-steel girder, thus forming the tension resisting abutment for the pressure-die of a hydraulic press, the pressure cylinder of which exercised the pressure P acting downward on pile 5 situated in the centre. The intensity of the pressure could be determined from the readings on the pressure gauge. The equally strong counter-force $-P$ acted in an extracting sense (mean lift h_m) on the first mentioned group of piles.