12

FOUNDATION INVESTIGATION

PROPOSED CENTRAL SHOP BUILDING

CALIFORNIA INSTITUTE OF
TECHNOLOGY
PASADENA, CALIFORNIA

CONDUCTED FOR

CALIFORNIA INSTITUTE OF TECHNOLOGY
1501 EAST CALIFORNIA STREET
PASADENA, CALIFORNIA

IN COOPERATION WITH

DAVIDSON AND MAURER
ARCHITECTS AND ENGINEERS

PROJECT NO. 64-468-A

JULY 31, 1964

CONVERSE FOUNDATION ENGINEERS
126 WEST DEL MAR BLVD. PASADENA, CALIFORNIA

FOUNDATION INVESTIGATION

The object of this investigation was to obtain information on the engineering properties of the subsurface soils on which to base recommendations for foundations under a one-story central shop building to be located on the west side of Holliston Avenue north of the existing Physical Plant at the California Institute of Technology, Pasadena, California. It is understood that structural loads will be carried to the ground as concentrated column loads with the maximum estimated to be on the order of 200 kips in an area where a craneway is to be constructed. In other portions of the structure, column loads are reported to vary from 35 kips to about 150 kips.

Field and Laboratory Investigation

A total of four borings were drilled at the approximate locations shown on Drawing 1, "Location of Borings." Depths ranged from 20 to 30 feet. Undisturbed samples were obtained from each boring for laboratory inspection and analysis of representative samples. Tests were performed to obtain information on the shear strength, moisture content, in-place density, and consolidation characteristics. The detailed log of borings and results of the tests are presented on Drawings 2, 3 4 and 5, "Summary of Borings" and on Drawing 6, "Consolidation Tests."

The sampling and testing procedures are described in the "Appendix" at the end of the report.

DISCUSSION AND RECOMMENDATIONS

General

The proposed building area is generally level and at the time of the field investigation consisted of two residential lots, each having an existing one-story stucco house in the central portion and frame garages at the rear. Trees cover a large portion of both lots.

It is understood that the planned floor slab elevation of the proposed new shop building will be about the same as the existing grade, with no appreciable grade changes anticipated.

Soil Strata

The soils in Borings 1 and 3, drilled near the north side of the building area were generally similar and consisted of a sandy silt zone, 9 to 14 feet deep, which merged to silty sand then alternating irregular layers of sand, silty sand and silt to the depths explored. Tests indicated that the upper portion of the sandy silt zone has low to moderate strength and is only slightly compressible at the existing moisture content, but loses strength and becomes quite compressible when saturated. The deeper soils are stronger and only slightly compressible regardless of moisture variations. In Borings 2 and 4, the sandy silt topsoil zone was only 2.5 to 7 feet thick and dense, well-graded sand was encountered at depths of 5.5 and 8.5 feet, respectively. The sand stratum continued to the depths investigated in both borings except for the thin silt layer at 16.5 feet in Boring 2. The strength characteristics of the mixed surficial soils in these two borings are comparable to the porous sandy silt in Borings 1 and 3. The underlying sand is strong and only slightly compressible.

No adverse moisture conditions were noted and none are expected on this site.

Foundation Recommendations

The upper soils are not considered satisfactory for structural support. It is recommended that the concentrated loads from the structure be carried to the strong, slightly compressible soils underlying the surficial zone. As an alternate, drilled and cast-in-place friction piles may be considered, but some problems due to caving may develop in drilling large diameter piles through the more sandy strata unless special precautions are taken.

Drawing D-1 gives recommended allowable bearing values for isolated pier footings placed at a depth of at least six feet below the lowest adjacent final surface and on firm non-porous soils comparable to those first encountered at the following depths in the borings:

Boring No.	Depth to Top of Bearing Stratum, feet
1	9.0
2	6.0
3	13.5
4	8.5

The solid line gives the recommended bearing value as limited by the soil shear strength and the dashed lines give the recommended allowable bearing value as limited by the estimated total settlements. The settlement estimates are based on the assumption that footings will be supported mainly by the mixed

soils comparable to those in Borings 1 and 3; where footings rest directly on a thick sand stratum comparable to that in Borings 2 and 4 the settlement will be slightly less. For either case, the settlement will occur rapidly as the initial loads are applied, with the major portion expected to have occurred by the time construction is completed. In those areas where sand is encountered, it is recommended that bells be extended no further than one foot into the sand to minimize the possibility of caving. All excavations should be inspected by the foundation engineer to be sure they are founded on the recommended soils and bells have been properly constructed and cleaned. Shafts should be at least 20 inches in diameter to allow passage of the clean out crews and the inspector. Casing requirements of the California State Division of Industrial Safety should be followed during construction.

Drawing D-2 gives the recommended allowable supporting capacities for a 24-inch diameter drilled and cast-in-place cylindrical pile. The capacity of other sizes will be proportional to the diameter. No closely spaced piles are anticipated. If any piles are placed closer than five diameters, center to center, the values shown should be reduced to account for the overlapping of soil stresses between adjacent piles. It is recommended that the following formula be used to calculate the efficiency of any closely spaced piles:

$$E = 1 - \frac{D\left[m(n-1) + n(m-1) + \sqrt{2}\,(m-1)(n-1)\right]}{\pi S m n}$$

Where E = Efficiency = $\frac{\text{Bearing capacity of pile in group}}{\text{Bearing capacity of isolated pile}}$

D = Diameter of pile in feet

S = Pile spacing, center to center, in feet

m = number of rows of piles

n = number of piles per row

The estimated settlement of piles is expected to be small, less than one-fourth inch, if loaded within the range of the curve on Drawing D-2.

No caving occurred during the foundation investigation and none is expected if reasonable precautions are taken during the drilling, and holes are filled with concrete as soon as practicable after the completion of drilling. Concrete should be poured through a tremie or similar device with the maximum height of free fall of concrete being limited to five feet. If any caving does occur which increases the diameter of the excavation more than 100 percent, the pile should be deepened for a distance equal to the height of the caved section. The weight of the pile may be assumed to be carried by end bearing.

Lateral Loads

The test results indicate that the allowable lateral bearing value of the surficial soils should be limited to 250 pounds per square foot per foot of depth. The maximum value should be limited to 3000 pounds per square foot. A coefficient of friction of 0.4 may be used in calculating the resistance to sliding of the bottoms of floor slabs cast on the compacted subgrade or base and the bottoms of grade beams which have been cast directly on the undisturbed natural soil.

Seismic Loads

The bearing values on Drawing D-1 and the pile supporting capacities on Drawing D-2 are for dead plus live loads only and may be increased 1/3 for combined dead, live and seismic loads.

Floor Slabs

It is expected that the removal of trees, building foundations and existing concrete slabs will result in considerable disturbance to the upper soils. It is recommended that all soils under slabs or pavement which have been disturbed by the removal of existing trees and structures be uniformly compacted to at least 90 percent of the maximum density as determined by the A.S.T.M. D1557-58T method. In those areas where no disturbance has occured, it is recommended that at least the upper 12 inches of material below the bottom of floor slabs and pavement be compacted to the degree recommended above.

Conclusion

The recommendations presented in this report represent our best engineering judgment based on the field and laboratory investigations which have been made. It is extremely important, because of the nonuniform character of the soils indicated by the borings, that all excavations be inspected by the foundation engineer before filling with concrete.

If you have any questions concerning this report or the recommendations which have been given, please do not hesitate to call.

Respectfully submitted,

CONVERSE FOUNDATION ENGINEERS

By Thomas D. Lake

Frederick J. Converse

Reviewed and approved

TDL:cs

Encl: Drawings 1-6, D-1, D-2

Dist: (5) Addressee

(1) Davidson and Maurer, Archs. and Engrs.

APPENDIX

Description of General Sampling and Laboratory Testing Procedures

Sampling

Undisturbed soil samples are obtained by forcing a special sampling tube into the undisturbed soils at the bottom of the boring. The sampling tube consists of a steel barrel 2. 50 inches inside diameter with a lining of one inch long thin brass rings. A special cutting tip is placed on one end and a double ball valve on the other. The sampling tube is driven approximately 18 inches into the soil and a 6 inch section of the central portion of the sample is taken for laboratory tests, the soil being still confined in the brass rings, after extraction from the sampling tube. The samples are taken to the laboratory in close fitting waterproof containers in order to retain the field moisture until completion of the tests. The driving energy is calculated as the average energy in foot-kips required to force the sampling tube through a measured distance of soil at the depth at which the sample is obtained.

Shear Tests

Shear tests are made with a direct shear machine of the strain control type in which the rate of deformation is approximately 0. 1 inches per minute. The machine is so designed that the tests are made without removing the samples from the brass liner rings in which they are secured. Each sample is sheared under a normal load equivalent to the weight of the soil above the point of sampling or estimated future weight of soil above this point. In some instances, samples are sheared under various normal loads in order to obtain the internal angle of friction and cohesion. Where considered necessary, samples are saturated and drained prior to shearing in order to simulate extreme field moisture condition.

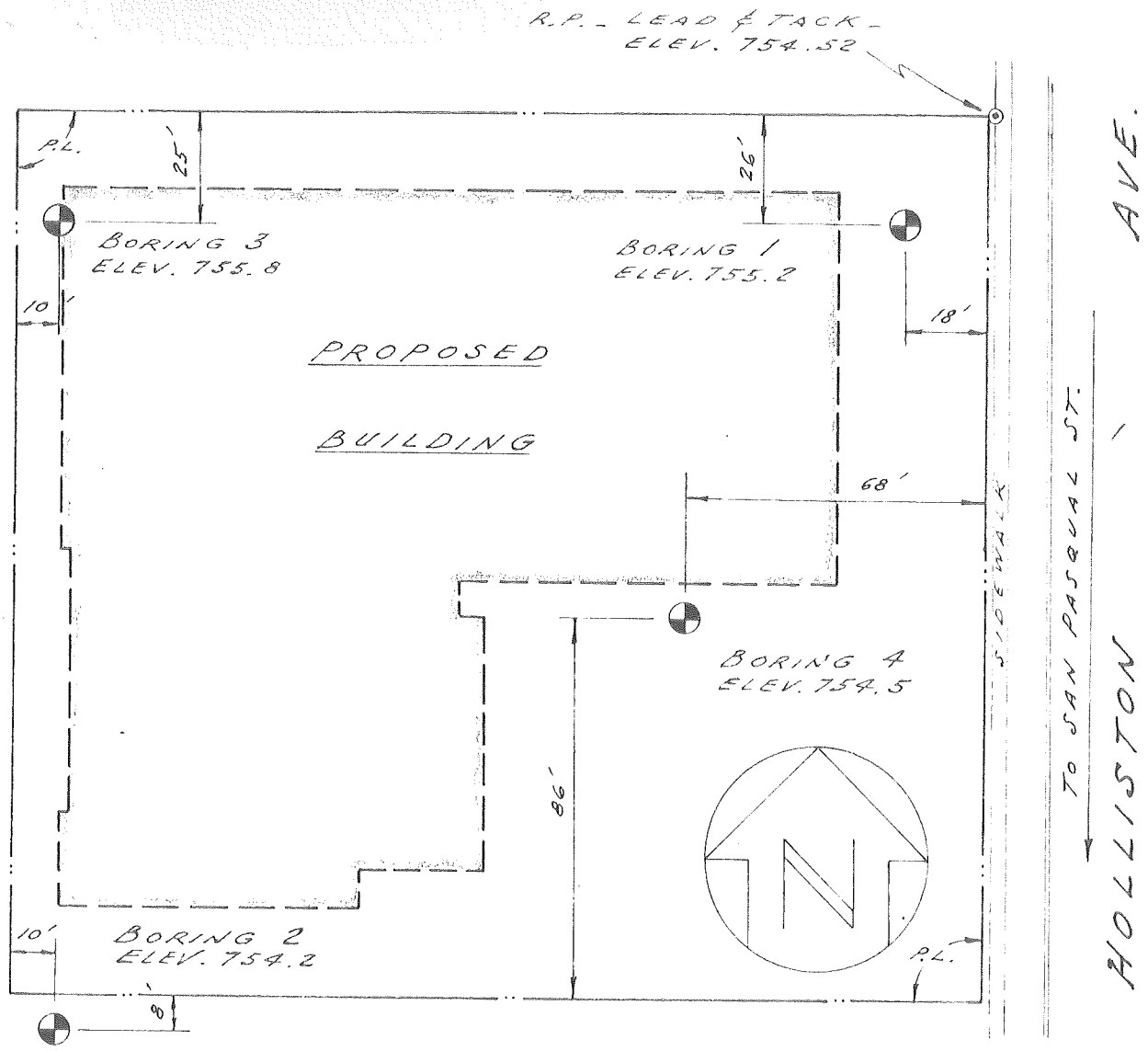
Triaxial shear tests are made on occasion, to check values obtained by the direct shear method.

Consolidation

The apparatus used for the consolidation tests is designed to receive one of the one inch high rings of soil as it comes from the field. Loads are applied in several increments to the upper surface of the test specimen, and the resulting deformations are recorded at selected time intervals. Porous stones are placed in contact with the top and bottom of each specimen to permit the ready addition or release of water.

Classification

The soils are classified in accordance with the Unified Soil Classification Chart adopted by the U. S. Corps of Engineers and Bureau of Reclamation. Where necessary, classification tests performed in accordance with ASTM procedures are made to substantiate visual classification. These tests might include mechanical analysis, Atterberg limits, and shrinkage tests.



REFERENCE - TOPOGRAPHIC MAP, DWG. NO. 11562, 1-18-63 BY BARNETT, HOPEN, SMITH & SALIT - SURVEYORS & PLAN BY DAVIDSON & MAURER - ARCHITECTS & ENGINEERS - LOS ANGELES, CALIFORNIA.

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LOCATION OF BORINGS

SCALE: 1" = 40'	PROPOSED CENTRAL SHOP BUILDING	DRAWING NO. 1
DWN BY: W. T. S.	CALIFORNIA INSTITUTE OF TECHNOLOGY	
DATE: 7/28/64	PASADENA, CALIFORNIA	

CONVERSE FOUNDATION ENGINEERS PASADENA, CALIFORNIA | PROJ. NO. 64-468-A

SUMMARY — BORING NO. 1

DATE: 7-20-64

ELEVATION: 755.2'

DEPTH IN FEET	SAMPLE NO				CODE CLASSIFICATION	DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WEIGHT	DRY DENSITY LB./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0	1	dry	soft / medium firm	dark brown	SANDY porous + occ. gravel to 1"		5.0	3.4	96.1	0.14 *
5	2	dry	firm	brown	SILTY SAND slightly porous + 5% gravel to 1"	ML	7.7	3.8	98.9	1.74
	3	dry	firm	brown	SILTY SAND slightly porous + 5% gravel to 1"	ML	9.5	5.8	106.6	2.59
10	4	sl. moist	dense	light brown	SILTY SAND fine slightly porous + 5% gravel to 1" +25% gr. & rock to 6"	SM	7.7	8.3	106.6	1.39
15	5	moist	dense	light brown	fine to coarse SAND +25% gravel & rock to 6"	SW	13.7	2.5	115.9	1.71
		moist	firm	brown	SILTY SAND + alt. silt streaks	SM & ML / SM				
	6	moist	dense	light brown	SAND +10% grav. to 3"	SW	9.7	8.9	105.3	1.40
20		moist	firm	brown	SILTY SAND fine +20% gr.-3" / fine to crs. +30% gravel to 3"	SM				
	7	moist	dense	light brown	fine to coarse SAND +30% gravel to 3"	SW	9.7	4.8	109.7	2.06
25										
30										

* Sample saturated and drained before testing

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PROPOSED CENTRAL SHOP BUILDING
CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIFORNIA

JOB NO. 64-468-A

CONVERSE FOUNDATION ENGINEERS PASADENA, CALIFORNIA

DRAWING NO. 2

SUMMARY — BORING NO. 2

DATE: 7-21-64

ELEVATION: 754.3'

DEPTH IN FEET	SAMPLE NO.					CODE CLASSIFICATION	DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WEIGHT	DRY DENSITY LB./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0	①		medium soft	brown	3" A.C. paving SANDY SILT + occasional gravel to 1"	ML		1.6	8.1	97.6	0.19 *
5	②		medium firm		fine to medium SILTY SAND slightly porous +5% gravel to 1"	SM		3.3	7.3	103.2	0.23 *
	③	moist	dense	light brown	fine +25% gravel to 3"	SW		5.7	4.8	109.1	0.69
10	④				to coarse +35% gravel to 3"			7.7	4.5	112.2	0.68
15	⑤				SAND			11.7	4.4	108.2	1.46
			medium firm	brown & light brown	SILT	ML					
	⑥		dense		fine to coarse SAND +30% gravel to 3" & alt. fine sand stks.	SW & SP		11.7	5.1	113.1	2.16
20											
25											
30											

* Sample saturated and drained before testing

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DRAWING NO 3

SUMMARY — BORING NO. 3

DATE: 7-21-64

ELEVATION 755.8'

DEPTH IN FEET	SAMPLE NO.				CODE CLASSIFICATION	DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WEIGHT	DRY DENSITY LB./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0		FILL	loose	gray	SILTY SAND +30% gr.1"	SM				
	①	dry	medium firm	brown	porous + occas. gravel		5.7	5.0	96.1	0.33 *
5	②	sl. moist			SANDY to 1"		7.7	6.0	104.6	1.46
	③			brown	slightly	ML	9.5	8.7	109.2	2.96
10	④		firm	& light brown	SILT +alternate silt streaks		9.7	13.9	105.1	3.67
15	⑤	moist		light brown	fine SILTY SAND	SM	7.7	6.1	97.0	1.16
			dense		fine to coarse SAND + occasional gravel to ½"	SW				
	⑥		firm & dense	brown	+occ.fine sand strks.	ML & SP	5.5	14.7	91.0	1.63
20	⑦		firm	& light brown	SILT	ML	7.7	24.7	85.3	1.78
25	⑧		dense	light brown	fine to coarse SAND +occ.gravel & alternate fine sand	SW & SP	9.7	2.6	114.3	2.30
					+10% gravel to 3"	SW				
					+20% gravel to 3"					
30					+40% gravel &rock to 9"					

* Sample saturated and drained before testing

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CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIFORNIA

JOB NO. 64-468-A

CONVERSE FOUNDATION ENGINEERS PASADENA, CALIFORNIA

DRAWING NO. 4

SUMMARY — BORING NO. 4

DATE: 7-21-64

ELEVATION: 754.5'

DEPTH IN FEET	SAMPLE NO					CODE CLASSIFICATION	DRIVE ENERGY FT. KIPS/FT.	FIELD MOISTURE % DRY WEIGHT	DRY DENSITY LB./CU. FT.	SHEAR RESISTANCE KIPS/SQ. FT.	
0	①	dry	medium soft	gray	2" A.C. paving (8" disturbed soil beneath) porous + occ.gravel to 2"			3.4	5.3	93.6	0.13 *
	②		medium firm	brown	SANDY slightly porous + occas. gravel	ML		5.0	5.9	102.9	1.15
5	③	sl.	firm	brown	SILT +5% gravel			12.0	6.8	118.0	2.41
				light	SILTY SAND + alt. sandy silt stks. to 3"	SM & ML					
	④	moist	dense	brown	fine to coarse +25% gravel to 3"	SW		13.7	3.8	116.2	1.13
10			&	&	+30% gravel & frequent silty sand strks. to 1"	&					
	⑤		firm	brown		SM		13.7	5.3	116.1	-
15		moist	dense	light	SAND + 30% gravel to 3"	SW					
	⑥			brown				13.7	4.8	115.1	2.14
20											
25											
30											

* Sample saturated and drained before testing

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JOB NO. 64-468-A

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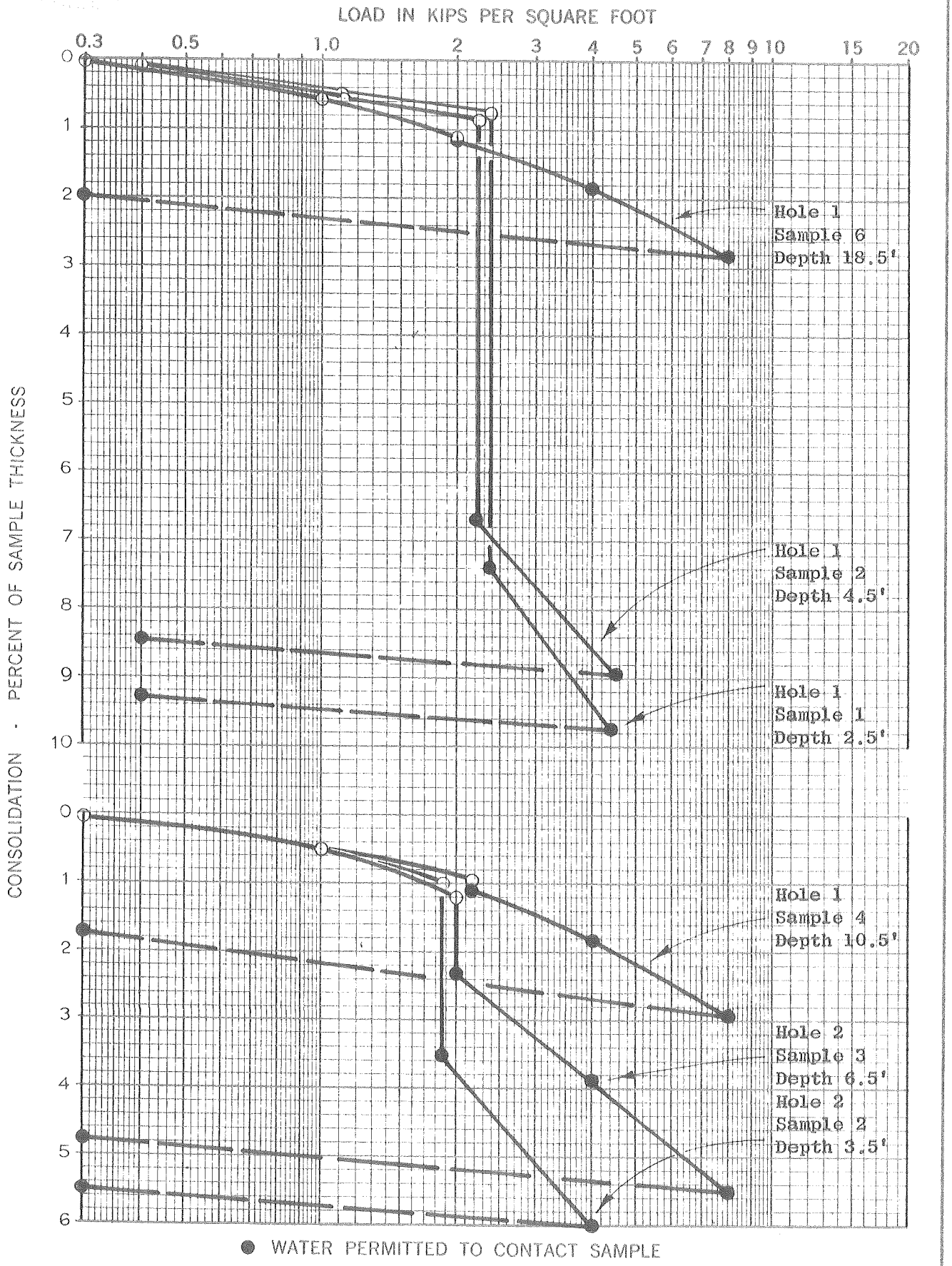
DRAWING NO. 5



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CONSOLIDATION TESTS

PROPOSED CENTRAL SHOP BUILDING
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PROJECT NO. 64-468-A

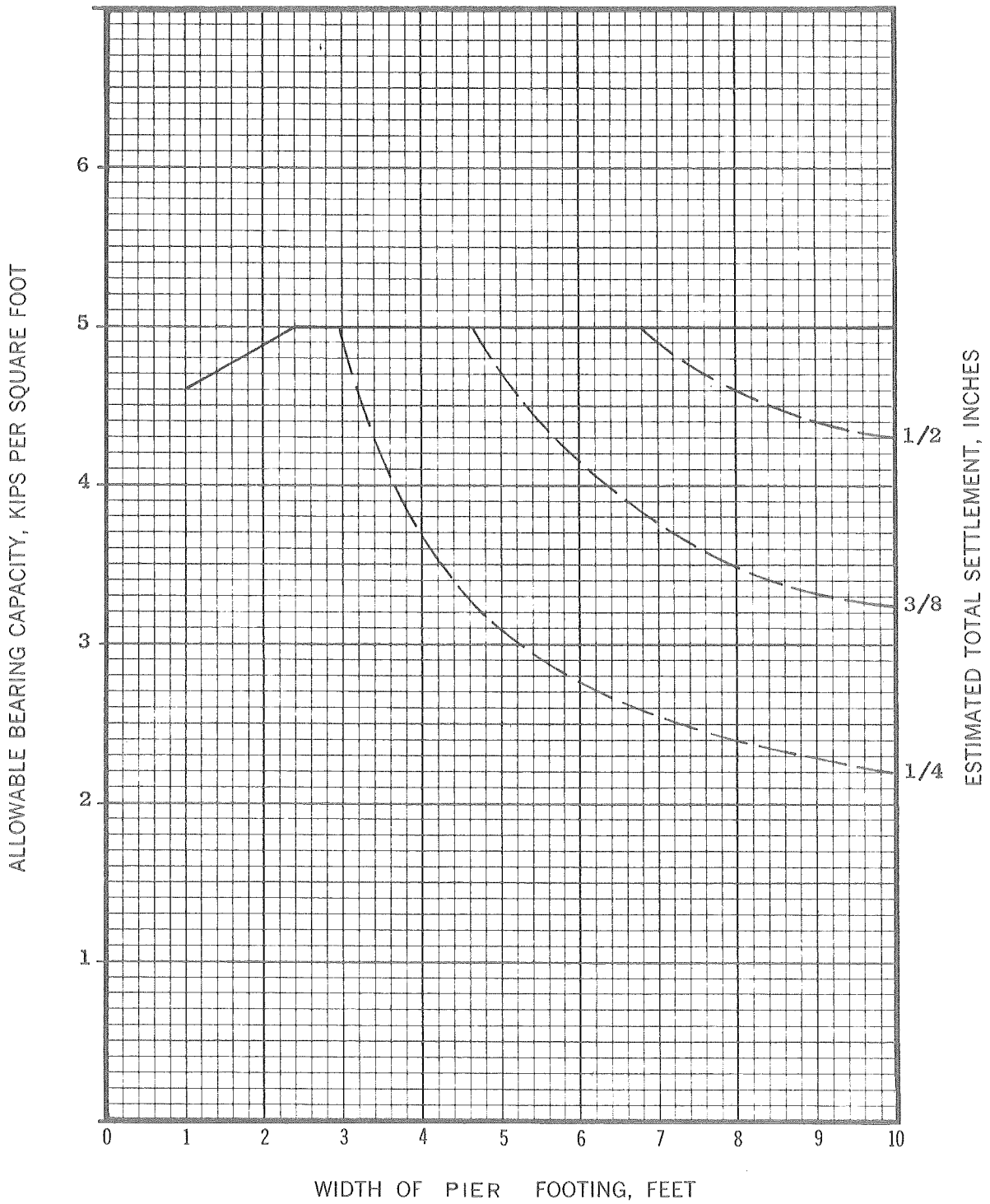
DRAWING NO. 6

PIER FOOTING DESIGN CURVES

ISOLATED FOOTINGS PLACED AT LEAST 6 FEET BELOW THE LOWEST ADJACENT FINAL SURFACE ON FIRM SILTY SAND OR SAND

——— BEARING CAPACITY AS LIMITED BY THE SOIL SHEAR STRENGTH

— — — BEARING CAPACITY AS LIMITED BY THE ESTIMATED TOTAL SETTLEMENT



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DRAWING NO. D-1

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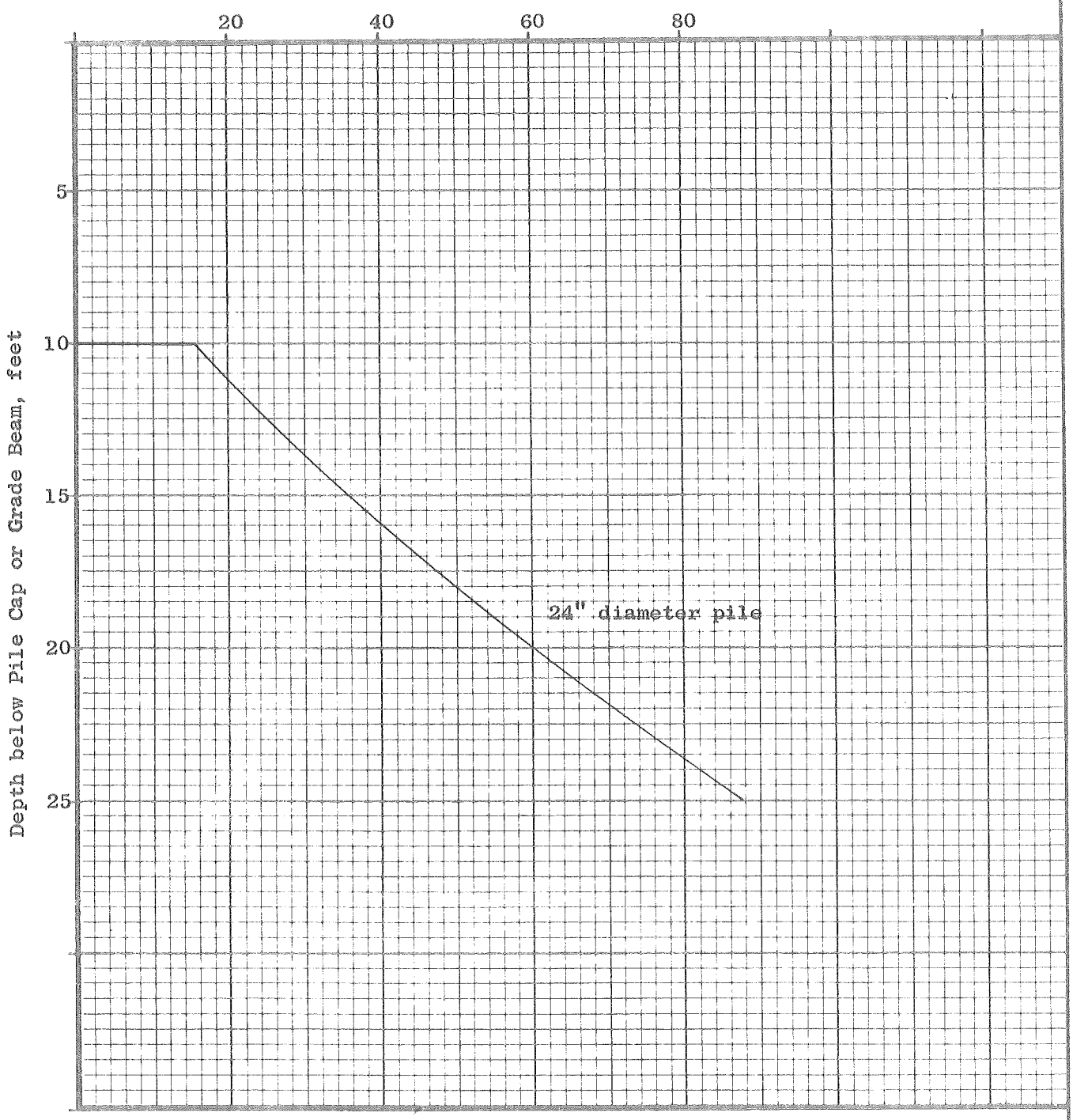
CAST - IN - PLACE PILE DESIGN



1. For pile groups, see efficiency factor formula in report.
2. The allowable load per pile is for dead plus live load and may be increased 1/3 for combined dead, live and seismic loads.
3. Elevation of pile cap assumed to be 3 feet or less below the existing ground surface.

PROPOSED CENTRAL SHOP BUILDING
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DRAWING NO. D-2

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