DRAFT FOR A REVISION OF PART 29 OF THE BOSTON BUILDING CODE

PREFACE BY A. CASAGRANDE

If someone would want to write a book on HOW NOT TO MAKE FRIENDS he might well suggest, as one of the most successful methods, serving on a committee for the drafting of the Part on FOUNDATIONS for a Building Code. Should the reader desire further proof for this statement he is invited to attend the meeting of this Society on February 19, 1958, when this new Draft will be open for general discussion. But even if he has no special desire to watch the trouncing of those who have written this new Draft for Part 29 of the Boston Building Code, but is merely anxious to learn the answer to questions that occur to him when reading this draft, he is welcome to attend the meeting and to state his questions. Readers who are not able to attend that meeting are invited to submit their comments in writing. Comments, either oral or written, should be concise.

In June, 1955, Mayor Hines appointed H. A. Mohr as chairman of an advisory committee to the Building Department to draft a long overdue revision of Part 29 — FOUNDATIONS — of the Boston Building Code. The other members appointed to that Committee were Henri D. A. Ganteaume, Harry J. Keefe, Maurice A. Reidy, Jr., and the writer.

Mr. Ganteaume served faithfully and exceedingly well until his death on October 15, 1956.

Mr. Mathoff, of the Boston Building Department, served as secretary of this committee and his comments, based on his extensive experience with the administration of the present Code, were most helpful.

In June 1957, the first draft of the revision was completed. In mimeographed form it was distributed to numerous engineers in Boston, as well as to a selected group of well-known foundation engineers throughout the country. From the comments received during the summer of 1957, it was realized that much more work was needed on this draft and a group of Boston engineers who had expressed willingness to serve as an informal review committee, met with the members of the original committee once a week in the period from September

to the end of December 1957. This group included: Henry Brask, F. E. Brown, Edwin W. Colby, James F. Haley, O. G. Julian, Wm. J. LeMessurier, Frank L. Lincoln, Mark Linenthal, Paul W. Norton, Waldo Pike, Richard C. Tousley, and Othar Zaldastani.

It was, of course, not possible to arrive at a unanimous agreement on all aspects of code requirements in this draft for Part 29. But the writer believes that on most of the vital points the final agreement was unanimous.

Based on the comments which will be received in the open meeting on February 19, and on those submitted in writing, a final revision of this draft will be prepared before it is submitted to the Mayor of Boston for further action.

At the final meeting on December 30, one of the senior members of the enlarged committee asked, half-jokingly, how much the City would have to pay if every participant in this effort would compute his time at his regular professional fee? Suffice to say that there are quite a number who have contributed hundreds of hours each, and that at a time when they could ill afford it because of their heavy regular working load.

PART 29.

EXCAVATIONS AND FOUNDATIONS.

Section

Section 2901. — Excavations.

(a) Until provision for permanent support has been made, excavations shall be properly guarded and protected by the persons causing them to be made so as to prevent such excavation from becoming dangerous to life or limb. Where necessary, excavations shall be sheet-piled, braced or shored, and permanent excavations shall be protected by retaining walls or other permanent structures to prevent movement or caving of the adjoining soil.

(b) Structures near an excavation and owned by another than the person causing the excavation to be made shall be supported as follows:—

(1) Where an excavation is carried below the curb grade, at the common property line, or below the surface of the ground where there is no such curb grade, the person causing such excavation to be made shall, at all times, if accorded the necessary license to enter upon the adjoining land, and not otherwise, at his own expense, preserve and protect from injury any wall, building or structure, the safety of which may be affected by said excavation, and shall support it by proper foundations. If the necessary license is not accorded to the person making such excavation, then it shall be the duty of the owner refusing to grant such license to make such wall, building, or structure safe and to support it by proper foundations; and, when necessary for that purpose, such owner shall be permitted to enter upon the premises where such excavation is being made.

(2) Where a party wall is intended to be used by the person causing the excavation to be made, he shall, at his own expense, preserve such party wall from injury and shall support it so that the said party wall shall be safe for the purposes intended.

(c) If the person whose duty it shall be under the provisions of this section to guard and protect an excavation, or to prevent adjoining soil from moving or caving, or to preserve or protect any wall, building, or structure from injury, shall neglect or fail so to do, the Commissioner may enter upon the premises, and make safe such excavation, wall, building or other structure as provided in section one hundred and sixteen of Part 1.

Section 2902. — General Requirements for Foundations.

(a) The foundations of every permanent structure shall be supported by satisfactory bearing material which shall mean:

(1) Natural deposits of rock, gravel, sand, rock flour (inorganic silt), clay, or any combination of these which does not contain an objectionable amount of organic matter;

(2) Compacted fills which satisfy the provisions of section twenty-nine hundred and four (a)(4);

(3) Natural deposits or artificial fills which can be changed into satisfactory bearing materials by pre-consolidation with a temporary surcharge in accordance with the provisions of section twenty-nine hundred and four (a)(5);

(b) Where footings are supported at different levels, or at different levels from footings of adjacent structures, foundation plans shall include vertical sections showing to true scale all such variations in grade. The effect of such differences in footing levels on the bearing materials shall be considered in the design.

(c) The foundations and grade beams of permanent structures, except when founded on rock, and except as otherwise provided in paragraph (d) of this section, shall be carried down at least four feet below an adjoining surface exposed to natural freezing. No foundation shall be placed on frozen soil. Foundations shall not be placed in freezing weather unless adequately protected.

(d) Foundations of detached garages or similar accessory structures not exceeding eight hundred square feet in area and not over one story high, and grade beams of all structures need not be carried more than one foot below an adjoining surface exposed to natural freezing if the underlying soil to a depth of at least four feet beneath the surface, and extending at least six feet outside the building, is sand, gravel, cinders or other granular materials containing not more than five per cent by weight passing a No. 200 mesh sieve.

(e) Structures subject to artificial freezing shall have adequate provisions to prevent damaging upheaval of foundations and floors.

(f) Basements or cellars shall be waterproofed up to a grade at least two feet above the maximum probable ground water level. Under boilers, furnaces and other heat producing apparatus, the waterproofing shall be protected against damage from heat.

Section 2903. — Soil Information.

(a) Before issuing a permit for the erection or alteration that will affect the foundation of a permanent structure, the Commissioner shall require the applicant to furnish adequate soil data. Where borings or tests are required, they shall be made at a sufficient number of locations and to such depths as are necessary to provide a reasonably complete understanding of the soil conditions underlying the site of the proposed structure. It is desirable that the scope of the soil investigation be discussed with the Commissioner beforehand. When it is proposed to support the structure directly on bedrock, the Commissioner may require drill holes or core borings to be made into the rock to a sufficient depth to prove that sound bedrock has been reached.

(b) Duplicate copies of the results obtained from all completed and uncompleted borings, plotted to true relative elevation and to scale, and of all test results or other pertinent soil data shall be filed with the Commissioner.

Section 2904. — Classification of Bearing Materials and Allowable Bearing Values.

(a) The terms used in this section shall be interpreted in accordance with generally accepted geological and engineering nomenclature. In addition, the following more specific definitions are used for bearing materials in the Greater Boston area.

(1) *Rocks.*

Shale — A soft, fine-grained sedimentary rock.
Slate — A hard, fine-grained sedimentary rock.
Roxbury Puddingstone — A hard, well-cemented conglomerate.

(2) *Granular Materials.*

Gravel — A mixture of mineral grains at least 70% (by weight) of which are more than one-quarter inch in diameter and possessing no dry strength.
Sand — A mixture of mineral grains which passes a No. 4 mesh sieve and which contains not more than 15% (by weight) passing a No. 200 mesh sieve.

Coarse Sand — A sand at least 50% (by weight) of which is retained on a No. 20 mesh sieve.
Medium Sand — A sand at least 50% (by weight)

of which passes a No. 20 mesh sieve and at least 50% (by weight) is retained on a No. 60 mesh sieve.

Fine Sand — A sand at least 50% (by weight) of which passes a No. 60 mesh sieve.

Well-graded Sand and Gravel — A mixture of mineral grains which contains between 25% and 70% (by weight) passing a No. 4 mesh sieve, between 10% and 40% (by weight) passing a No. 20 mesh sieve, and containing not more than 8% (by weight) passing a No. 200 mesh sieve.

(3) *Cohesive Materials.*

Hardpan — A glacial till that generally overlies directly bedrock and consists of a highly compacted, heterogeneous mixture ranging from very fine material to coarse gravel and boulders. It can be identified from geological evidence and from the very high penetration resistance encountered in earth boring and sampling operations.

Clay — A fine-grained, inorganic soil possessing sufficient dry strength to form hard lumps which cannot readily be pulverized by the fingers.

Hard Clay — An inorganic clay requiring picking for removal, a fresh sample of which cannot be molded in the fingers.

Medium Clay — An inorganic clay which can be removed by spading, a fresh sample of which can be molded by a substantial pressure of the fingers.

Soft Clay — An inorganic clay, a fresh sample of which can be molded with slight pressure of the fingers.

Rock Flour and Inorganic Silt — A fine-grained, inorganic soil consisting chiefly of grains which will pass a No. 200 mesh sieve, and possessing sufficient dry strength to form lumps which can readily be pulverized with the fingers.

(Note: Dry strength is determined by drying a wet pat of the soil and breaking it with the fingers.)

(4) *Compacted Granular Fill.*

A fill consisting of granular materials (gravel, sand-

gravel mixtures, sand, crushed stone, slag, or cinders) containing not more than five per cent (by weight) passing a No. 200 mesh sieve, shall be considered satisfactory bearing material when compacted by one of the following methods:

I. In six-inch layers, each layer with at least four coverages with the treads of a crawler-type tractor with a total weight, including equipment, of not less than fifteen tons and operated at its top speed;

II. In twelve-inch layers, with at least three coverages with the wheels of a rubber-tired roller having four wheels abreast and weighted to a total load of not less than thirty-five tons;

III. Other types of materials and other compaction equipment and procedures may be approved by the Commissioner on the basis of sufficient evidence that they will achieve compacted fills having satisfactory properties.

Application of water is permitted, and for uniform sands may be required in order to achieve satisfactory trafficability and compaction.

The Commissioner shall require a competent inspector, qualified by experience and training and satisfactory to him, to be on the work at all times while fill is being placed and compacted. The inspector shall make an accurate record of the type of material used, including grain size curves, number of coverages and type of compaction equipment, the use of water and other pertinent data. Whenever the Commissioner or the inspector questions the suitability of a material, field density and laboratory compaction tests shall be made by a competent soils engineer in order to determine the degree of compaction achieved. A copy of all these records and test data shall be filed with the Commissioner.

(5) *Preloaded Unsatisfactory Materials.*

The Commissioner may allow the use of certain unsatisfactory natural soils and uncompacted fills for the

support of one story structures, after these materials have been preloaded to not less than one-hundred and fifty per cent of the stresses which will be induced by the structure. The Commissioner shall require loading and unloading of a sufficiently large area, conducted under the direction of an approved, experienced soils engineer, who shall submit a report which demonstrates that the compressibility of the preloaded material will not cause objectionable settlements of the structure.

(b) The maximum pressure on soils under foundations shall not exceed the allowable bearing values set forth in the following table, except when determined in accordance with the provisions of sections twenty-nine hundred and fifteen and twenty-nine hundred and sixteen, and in any case subjected to the modifications of subsequent paragraphs of this section.

CLASS	MATERIAL	Allowable Bearing Value in Tons per Square Foot (*)
1	Massive igneous rocks and Roxbury Puddingstone, all in sound condition (sound condition allows minor cracks)	100
2	Slate in sound condition (minor cracks allowed)	35
3	Shale in sound condition (minor cracks allowed)	10
4	Residual deposits of shattered or broken bedrock of any kind except shale	10
5	Hardpan	10
6	Gravel, well-graded sand and gravel	5
7	Coarse sand	3
8	Medium sand	2
9	Fine sand	1
10	Hard clay	5
11	Medium clay	2
12	Soft clay	1
13	Rock flour, inorganic silt, shattered shale, or any natural deposit of unusual character not provided for herein	(**)
14	Compacted granular fill	2 to 5 (**)
15	Preloaded unsatisfactory materials	(**)

*The allowable bearing values given in this section, or when determined in accordance with the provisions of section twenty-nine hundred and fifteen, will assure that the soils will be stressed within limits that lie safely below their strength. However, such allowable bearing values do not assure that the settlements will not exceed the tolerable limits for a given structure.

**Value to be fixed by the Commissioner.

(c) The tabulated bearing values for rocks of Classes 1 to 3 inclusive shall apply where the loaded area is on the surface of sound rock. Where the loaded area is below such surface these values may be increased ten per cent for each foot of additional depth, but shall not exceed twice the tabulated values.

(d) The bottom surface of any footing resting on materials of Classes 4 to 15 inclusive shall be at least eighteen inches below the lowest ground surface immediately adjacent to the footing.

(e) The allowable bearing values of materials of Classes 4 to 9 inclusive may exceed the tabulated values by five per cent for each foot of depth of the loaded area below the minimum required in paragraph (d), but shall not exceed twice the tabulated values. For areas of foundations smaller than three feet in least lateral dimension, the allowable design bearing values shall be one-third of the allowable bearing values multiplied by the least lateral dimension in feet.

(f) Whenever there is any doubt about the settlements of a proposed structure or the effect on neighboring structures, the Commissioner shall require that the magnitude and distribution of the probable settlements be investigated as specified in section twenty-nine hundred and sixteen. Otherwise, the tabulated bearing values for Classes 10 to 12 inclusive shall apply only to pressures directly under individual footings, walls, and piers; and in case structures are founded on or are underlain by deposits of these classes, the total load over the area of any one bay or other major portion of the structure, minus the weight of excavated material, divided by the area, shall not exceed one-half the tabulated bearing values.

(g) Where the bearing materials directly under a foundation overlie a stratum having smaller allowable bearing values, these smaller values shall not be exceeded. Computation of the vertical pressure in the bearing materials at any depth below a foundation shall be made on the assumption that the load is spread uniformly at an angle of sixty degrees with the horizontal; but the area considered as supporting the load shall not extend beyond the intersection of sixty degree planes of adjacent foundations.

(h) Whenever, in an excavation, soil and ground water conditions are such that an inward or upward flow of seepage is produced in the bearing material, special excavating methods and control of ground water shall be employed to prevent disturbance to the bearing material. If there is evidence of disturbance of the bearing material,

the extent of the disturbance shall be evaluated and appropriate remedial measures taken, satisfactory to the Commissioner.

Section 2905. — Foundation Design.

(a) Foundations shall be designed to distribute to the supporting materials all vertical, horizontal and inclined loads, as specified in section twenty-nine hundred and five, without exceeding the allowable stresses specified elsewhere in this Code for the materials of which the foundations are to be constructed. Concrete in all foundations shall be proportioned for an ultimate strength of at least two thousand pounds per square inch.

(b) The loads to be used in computing the maximum pressure upon bearing materials under foundations shall be the live and dead loads of the structure, as specified in Part 23, including the weight of the foundations, but excluding loads from overlying soil. Foundation mats or floors resting on the ground shall be designed to resist the maximum probable hydrostatic uplift.

(c) Eccentricity of loading in foundations shall be fully investigated and the maximum pressure on the basis of straight-line distribution shall not exceed the allowable bearing values.

(d) Where the pressure on the bearing material due to wind is less than one-third of that due to dead and live loads, it may be neglected in the foundation design. Where this ratio exceeds one-third, foundations shall be so proportioned that the pressure due to combined dead, live and wind loads shall not exceed the allowable bearing values by more than one-third.

(e) One story structures not exceeding eight-hundred square feet in area and having no masonry walls may be built on spread foundations founded on a crust not less than three feet thick of satisfactory bearing material which is underlain by unsatisfactory bearing material, provided, however, that the stresses induced in the unsatisfactory material by the to-be-added live and dead loads including that of new fill, if any, within or adjacent to the building area, will not exceed two-hundred and fifty pounds per square foot.

(f) The earth pressure against foundation walls and other types of retaining walls shall be determined in accordance with Soil Mechanics principles. Particular attention shall be paid to the type of backfill, drainage and the lateral support which may cause substantially larger earth pressures than the active earth pressure. In addition, such

walls shall be designed for a hydrostatic pressure corresponding to the maximum probable ground water level.

Section 2906. (Now included in Section 2905).

Section 2907. — Footings and Foundation Piers.

(a) The footings of foundation walls or piers shall be of plain or reinforced concrete or other satisfactory masonry or steel grillages. Structural steel grillage foundations shall have at least six inches of net concrete cover below the bottom of the steel and shall have at least four inches of net concrete cover above the steel and between the sides of the steel and the adjacent soil. Footings of wood may be used under temporary structures.

(b) Foundation Piers are here defined as structural members, built in an excavation, or made by filling an excavated shaft with concrete, extending to a satisfactory bearing material.

(1) The manner of construction shall be by non-displacement methods and shall permit manual inspection of the bearing material in place.

(2) The bases of foundation piers may be enlarged by spread footings, pedestals or belled bottoms.

(3) Foundation piers built within excavations that are then backfilled by an approved method and those built by filling the excavated shafts with concrete, may be designed as continuously supported columns.

(4) Bell-shaped bases shall have a minimum edge thickness of four inches. The roof shall slope not less than sixty degrees with the horizontal unless the bases are designed in accordance with Part 26.

(5) When the center of cross section of a foundation pier at any level deviates from the center of the load more than one-sixtieth of its height, or more than one-tenth of its diameter, it shall be reinforced as provided in Part 26.

(6) With the approval of the Commissioner concrete may be placed through still water by means of a properly operated tremie or bottom-dump bucket.

Section 2908. — Driven Piles — General Requirements.

(a) Types of pile construction not specifically provided for in this

part shall meet such additional requirements as may be prescribed by the Commissioner.

(b) A detached column supported by piles shall rest upon not less than three piles; except that for one story buildings a detached column may rest upon two piles when its axis is not more than one and one-half inches off the line connecting the centers of the two piles, or upon a single pile when other than wood or wood-composite piles are used, and its axis is not more than one and one-half inches off the center of the pile.

(c) A foundation wall, if properly restrained laterally both during and after construction, may be supported by a single row of piles.

(d) The method of driving shall be such as not to impair the strength of the pile and shall meet with the approval of the Commissioner. Shattered, broomed, crumpled or otherwise damaged pile heads shall be cut back to sound material before continuing the driving.

Followers — A follower shall be of steel, seasoned white oak or hickory, equipped on its lower end with a metal socket or hood suitable for encasing the pile head and to protect it from being damaged during driving.

Cushion Blocks — Except for wood piles, a cushion block consisting of a material equivalent in its elastic properties to that of seasoned white oak or hickory, enclosed in a metal housing to prevent its lateral deformation, shall be placed between the hammer plunger and the top of the pile.

(e) Jetted piles shall be driven to the required resistance after the flow of jet water has stopped, except as provided in section twenty-nine hundred and nine, paragraph (d)(5).

(f) Additional piles shall be driven to replace piles that have been driven in locations other than those indicated on the plans, damaged, or that have capacities less than required by the design, if such deficiency causes objectionable effects in the supported structure. In such cases the affected pile groups and pile caps shall be investigated and, if necessary, redesigned.

(g) Concrete capping for piles shall be proportioned for an ultimate strength of at least two thousand pounds per square inch. The concrete shall extend not less than twelve inches above the pile heads and shall fill the space between and around the piles for a depth of at least three inches. The minimum horizontal distance from the edge of the pile cap to the nearest pile surface shall be six inches and there

shall be at least two inches of concrete between the top of a pile and steel reinforcement.

(h) Where piles are driven through soft soil to hard bearing material providing high point resistance, the grades of all piles or pile castings previously driven or redriven shall be measured to detect uplift; and if uplift of one-half inch or more occurs in any pile or pile casing, such pile or pile casing shall be redriven to its original point elevation and thereafter to the required final driving resistance.

(i) The Commissioner shall require the owner to engage a competent inspector, qualified by experience and training and satisfactory to the Commissioner, to be on the work at all times while piles are being driven. The inspector shall make an accurate record of the material and the principal dimensions of each pile, of the weight and fall of the ram, the type, size and make of hammer, the number of blows per minute, the energy per blow, the penetration of each pile for the last fifteen blows, together with the grades at point and cut-off. A copy of these records shall be filed in the office of the Commissioner.

Section 2909. — Allowable Load on Piles

(a) The supporting capacity of piles shall be obtained from bearing upon or embedment in bearing materials as defined in section twenty-nine hundred and four.

(b) The allowable pile load shall be limited by the provision that the vertical pressures in the bearing materials below the points of the piles produced by the loads on all piles in a foundation shall not exceed the allowable bearing values of such materials, as specified in sections twenty-nine hundred and four, twenty-nine hundred and fifteen, and twenty-nine hundred and sixteen. Piles or pile groups shall be assumed to transfer their loads to the bearing materials by spreading the load uniformly at an angle of sixty degrees with the horizontal, starting at a polygon circumscribing the piles at the top of the satisfactory bearing material in which they are embedded, but the area considered as supporting the load shall not extend beyond the intersection of the sixty degree planes of adjacent piles or pile groups.

(c) The allowable load on each pile shall be further limited by the requirement that such load shall not cause excessive movement of the pile relative to the soil. Satisfactory proof of this load for all soil conditions and all types of piles can be obtained from load tests conducted in accordance with section twenty-nine hundred and fifteen. In

the absence of such proof of the supporting capacity, the load on a single pile shall not exceed the higher of the two values determined in accordance with paragraphs (d) and (e) of this section.

(d) The allowable load may be computed from the driving resistance as follows:

(1) Driving formula

$$R = \frac{k\ E}{s + c}$$

where

R = allowable pile load in pounds

E = energy per blow which for drop hammers and single-acting steam hammers is the product of the weight of the striking part of the hammer and the height of fall in feet, and which for other types of hammers must be verified in a reliable manner when determining the penetration s.

k = a constant which is 2.0 for wood piles, and 1.6 for all other types of piles.

s = average penetration per blow, for the last five blows, in inches.

c = a constant which is 1.0 for drop hammers, and 0.1 for all other types of hammers.

(2) For allowable pile loads of more than forty tons the energy E per blow delivered by the hammer shall be numerically not less than one-eighth of R.

(3) For double-acting and differential steam hammers and Diesel hammers, the value of "s" must be determined with the hammer operating at not less than 90% of the maximum number of blows per minute for which the hammer is designed.

(4) The data used in determining driving resistance shall be obtained during the driving and not upon re-driving when a pile has been allowed to stand more than one hour after having been driven.

(5) When any type of tapered pile is to be driven through a layer of material of Classes 6 to 10 inclusive and Class

14 exceeding five feet in thickness, and through an underlying soft stratum, the bearing capacity shall not be determined in accordance with the driving formula unless jetting is used through said layer during the entire driving of the pile.

(e) The allowable load on a pile stopped in inorganic clay as found in Greater Boston, may be based on a friction value of six-hundred pounds per square foot of embedded pile surface. The embedded length shall be the length of the pile below the surface of the inorganic clay, or below the surface of immediately overlying satisfactory bearing material. The embedded pile-surface-area shall be obtained by multiplying the embedded length with the perimeter of the smallest circle or polygon that can be circumscribed around the average section of the embedded length of the pile. The method of determining the allowable load described in this paragraph shall not be used for a pile in which the drive-pipe is withdrawn.

(f) When piles in clusters are driven under the provisions of paragraph (e), the allowable load shall be computed for the smaller of the following two areas: (1) the sum of the embedded pile-surface-areas; (2) the area obtained by multiplying the perimeter of the polygon circumscribing the cluster at the surface of the satisfactory bearing material with the average embedded length of piles.

(g) The allowable load on a single pile installed by jacking shall not exceed one-half the load applied to the pile at the completion of jacking, provided that the final load is kept constant for a period of four hours and that the settlement during that period does not exceed one-twentieth of an inch.

Section 2910. — Wood Piles.

General Requirements

(a) Every wood pile shall be in one piece, cut from a sound live tree, and free from defects which may materially impair its strength or durability. It shall be butt-cut above the ground swell, and shall have substantially uniform taper from butt to point. Wood piles shall measure at least six inches in smallest diameter at the point, at least ten inches in smallest diameter at the cut-off, these measurements being taken under the bark. The axis of a wood pile shall not deviate from a straight line more than one inch for each ten feet of length nor more than six inches for the entire length.

(b) The load on a wood pile shall not exceed the allowable load specified in section twenty-nine hundred and nine and, for a pile of the minimum dimensions specified in this section, shall not exceed twelve tons for Spruce, Norway Pine, and woods of similar strength which will be referred to as Type A, nor sixteen tons for Oak, Southern Yellow Pine, and woods of similar strength which will be referred to as Type B. These loads may be increased for each full inch by which both the cut-off and point diameters exceed the minima specified, by three tons for woods of Type A, but not to exceed a total load of twenty-four tons; and by four tons for woods of Type B, but not to exceed a total load of thirty tons.

(c) Piles shall be cut to sound wood before capping is placed.

(d) The center-to-center spacing of wood piles shall be not less than two and one-half times the cut-off diameter.

(e) The size of the hammer shall be such that the driving energy in foot-pounds per blow shall not exceed numerically the point diameter of the pile in inches multiplied by fifteen-hundred. The total driving energy in foot-pounds for six inches of penetration shall for all types of hammers be numerically no greater than the point diameter in inches times twenty-two-thousand for woods of Type A or times thirty-two-thousand for woods of Type B. For the last inch of penetration the energy in foot-pounds shall not exceed numerically the point diameter in inches multiplied by six thousand for woods of Type A and seven-thousand five-hundred for woods of Type B.

(f) The cut-off grade for untreated-wood piles shall be below the probable permanent ground-water level, and shall be subject to the Commissioners approval.

(g) *Additional Requirements for Treated Piles.*

(1) Timber piles pressure treated with creosote or creosote-coal-tar solutions, and conforming to the requirements of this section, may be cut off above permanent ground water level when used for the support of buildings of Type V or VI or for one-story buildings of other types.

(2) Before any treated piles are driven, the Commissioner shall be furnished three copies of a certificate of inspection, issued by an approved independent testing laboratory, certifying that the piles were free of decay, were properly peeled and otherwise prepared before treat-

ment; and that the method of treatment, the chemical composition and the amount of retention of the preservative conform to the requirements of this section.

(3) Treated piles shall be of Norway Pine, Southern Yellow Pine or Douglas Fir and shall be impregnated with preservative in accordance with standards C1-57 and C3-57 of the American Wood Preservers' Association, or as required by the Commissioner.

(4) Piles exposed to sea water shall be Southern Yellow or Norway Pine treated with Grade B creosote-coal tar solution, conforming to standard P2-57 of the American Wood Preservers' Association. Piles not so exposed shall be treated with creosote conforming to standard P1-54 of the American Wood Preservers' Association.

(5) The retention of preservative shall be not less than twenty pounds per cubic foot for piles exposed to sea water and not less than twelve pounds for other piles.

(6) After being cut to grade, the top surface of the pile shall be brush treated with not less than three heavy coatings of the treating material applied hot.

Section 2911. — Precast Concrete Piles

(a) Precast concrete piles shall be so proportioned, cast, cured, handled and driven as to resist without perceptible cracking the stresses induced by handling and driving as well as by loads. The minimum lateral dimension of a precast concrete pile shall be twelve inches at cut-off and eight inches at the point exclusive of the metal point, if used. Each pile shall be cast in one piece. The concrete shall have a minimum compressive strength of three thousand pounds per square inch and shall fulfill other requirements of Part 26. No pile shall be handled or driven until it has cured sufficiently to develop the necessary strength as shown by standard test specimens made from the same batches of concrete cured under similar conditions.

(b) Piles shall be proportioned so as to satisfy the requirements of Part 26. Additional requirements are as follows: For a length equal to at least three times the minimum lateral dimension at both ends of the pile, lateral ties shall be spaced not over three inches center-to-center or an equivalent spiral shall be provided. Reinforcing steel shall be embedded in concrete forming the body of the pile a

net distance of at least one and one-half inches from any exposed surface and in piles exposed to sea water such coverage shall be at least three inches.

(c) The maximum water-cement ratio and the minimum cement content of the concrete for piles exposed to sea water shall be 4.5 gallons per sack, and 8 sacks per cubic yard, respectively.

(d) The minimum spacing center-to-center of precast concrete piles shall be two and one-half times the square root of the cross-sectional area at the butt.

(e) When precast concrete piles are driven to or into bearing materials of Classes 1 to 5 inclusive, or through materials containing boulders, they shall have metal tips of approved design.

(f) The load on a precast concrete pile shall not exceed the allowable load specified in section twenty-nine hundred and nine, and shall not exceed fifty tons for a pile of one square foot cross-sectional area. For piles of larger cross-section, this limit of load may be increased in proportion to increase in area, but not to exceed a total load of eighty tons.

Section 2912. — Cast-in-place Concrete Piles.

(a) In this section a distinction is made between poured-concrete piles and compacted-concrete piles. A poured-concrete pile is formed by pouring concrete into a driven casing or drive-pipe that is installed in the ground either permanently or temporarily. A compacted-concrete pile is formed by placing concrete having zero slump, in small batches, and compacting each batch.

(b) All cast-in-place concrete piles shall be so made and placed as to ensure the exclusion of all foreign matter and to secure a well-formed unit of full cross section. While placing the concrete the casing or drive-pipe shall be free of water.

(c) *Poured-Concrete Piles.*

(1) The diameters of metal-cased poured-concrete piles, when measured on the outside of a plain cylinder, or of horizontal, helical or vertical corrugations, shall be not less than eight inches one foot above the point, nor less than twelve inches sixteen feet above the point. The shape of the pile may be cylindrical, or conical, or a combination thereof, or it may be a succession of cylin-

ders, with the change in diameter of adjoining cylinders not exceeding one inch.

(2) For uncased poured-concrete piles (i.e. when no metal casing is left in the ground) the outside diameter of the drive-pipe shall be not less than fifteen inches.

(3) The load on poured-concrete piles shall not exceed the allowable load specified in section twenty-nine hundred and nine, nor twenty-two and one-half per cent of the twenty-eight day strength of the concrete, but not exceeding 900 pounds per square inch, when applied to the cross-sectional areas computed on the following basis:

for metal-cased piles driven to or into materials of classes 1 to 5 inclusive, using the diameter measured one foot above the point and as further specified in paragraph (1), minus one-half inch.

for metal-cased piles driven into materials of classes 6 to 14 inclusive, using the diameter at the surface of the bearing stratum in which the pile receives its support, and as further specified in paragraph (1), minus one-half inch.

for uncased piles driven to or into any bearing material, using the inside diameter of the drive pipe minus two inches.

In no case shall the maximum load on a poured-concrete pile exceed seventy-five tons.

(4) The spacing of poured-concrete piles shall be such as to ensure the preservation of the full cross-section. The spacing center-to-center shall be not less than two and one-half times the outside diameter of the casing or drive-pipe at cut-off. Where the center-to-center spacing is thirty-six inches or less, no casing or drive-pipe shall be filled with concrete until all casings or drive-pipes within a radius of five feet have been driven to the required resistance.

(d) *Compacted Concrete Piles*

The load on compacted concrete piles shall be limited by the provisions of sections twenty-nine hundred and eight and twenty-

nine hundred and nine paragraph (b), except that the circumscribing polygon shall start at the junction of the shaft and the enlarged base, and the bearing area shall be taken at planes six feet or more below said junction; nor shall the allowable load on a compacted concrete pile exceed one hundred and twenty tons. The installation of such piles shall fulfill the following listed requirements:

(1) The drive-pipe used for installing the pile shall be not less than twenty-inches outside diameter.

(2) The enlarged base of the pile shall be formed on or in bearing materials of Classes 1 to 8 inclusive.

(3) The concrete shall have a twenty-eight day strength of at least 3750 pounds per square inch, shall have zero slump, and shall be placed in batches not to exceed five cubic feet in volume.

(4) The last batch of concrete shall be driven into the enlarged base with not less than twenty blows, each of not less than one hundred and thirty thousand foot-pounds.

(5) As the drive-pipe is being withdrawn, not less than two blows of not less than thirty thousand foot-pounds shall be applied to compact each batch of shaft concrete.

(6) An uncased shaft shall not be formed through organic or inorganic clay or silt unless an excavation at least equal to the inside diameter of the drive-pipe is first augured through such soil, or the individual piles are located more than nine feet apart.

(7) A permanent metal-cased shaft, not less than sixteen inches in diameter, shall be formed through organic or inorganic clay or silt if requirement (6) is not fulfilled. The permanent metal casing shall be fastened to the enlarged base in such a manner that the two will not separate. The concrete may be placed in the metal casing in the same manner as for poured-concrete piles. No metal casing shall be filled with concrete until after all piles within a radius of at least nine feet have been driven. The allowable load on the shaft shall be limited as specified for concrete-filled steel pipe piles in paragraph (b) of section twenty-nine hundred and thirteen.

(8) The center-to-center spacing of piles shall be not less than four feet and six inches.

Section 2913. — Steel and Steel-Concrete Piles.

(a) At locations where steel piles will be in contact with sea water, organic soils, cinders, slag or any fill containing material that might attack steel, the surface of the piles shall be effectively protected against contact with such materials.

(b) *Concrete-filled Pipe Piles.*

(1) Piles consisting of steel pipes and concrete-filled after driving shall have an outside diameter of not less than ten and three-quarters inches and a pipe wall-thickness of at least two-tenths of an inch. Splices shall be welded to one hundred per cent of the strength of the pipe. Pipes may be driven open-ended or closed-ended, and the provisions of this section apply to both types.

(2) After driving, the inside of the pipe shall be carefully cleaned to the bottom and its curvature and cross section verified to the satisfaction of the Commissioner. The diameters shall not vary more than twenty per cent from the original value. Pipes shall be filled with concrete having an ultimate strength at twenty-eight days of at least three thousand pounds per square inch and as further specified in Part 26. Concrete shall not be placed through water.

(3) The center-to-center spacing of concrete-filled pipe piles shall be not less than two and one-half times the outside diameter of the pipe.

(4) The load on concrete-filled pipe piles shall not exceed the allowable load determined in accordance with section twenty-nine hundred and nine, nor the load on the concrete at twenty-two and one-half per cent of the twenty-eight day strength, but not exceeding nine hundred pounds per square inch, plus the load on the steel at eight thousand pounds per square inch; nor shall the load carried by the steel exceed one-half the total load on the pile.

(c) *H Piles.*

(1) Rolled steel H or other approved sections having a minimum thickness of metal of 0.4 inch may be used as piles. They shall be spliced to one hundred per cent of the strength of the section.

(2) The center-to-center spacing of such piles shall be not less than two and one-half times the width of the flange.

(3) The load on such piles shall not exceed the allowable load determined in accordance with section twenty-nine hundred and nine, nor seven thousand pounds per square inch on the area of the cross section.

(d) *Concrete-filled Pipes with Steel Cores.*

(1) The pipe shall be so installed that its lower end is firmly seated in bedrock of Classes 1, 2 or 3. It shall be of sufficient diameter to permit manual inspection of the bedrock socket. Splices shall be welded to one hundred per cent of the strength of the pipe.

(2) A socket, approximately of the inside diameter of the pipe, shall be made in bedrock of Classes 1 or 2 to a depth that will assure load transfer when computed for a bearing on the bottom surface of the socket in accordance with paragraphs (b) and (c) of section twenty-nine hundred and four, acting together with a bond stress on the perimeter surface of the socket of one hunded pounds per square inch.

(3) The steel core shall consist of a structural steel member. The ends of the sections of the core shall be milled for bearing and the splices shall be so made as to safely withstand the stresses developed during installation. The steel core shall be centered in the steel pipe and shall rest on a layer of cement grout on the bottom of the socket.

(4) Concrete shall have a minimum compressive strength of four thousand pounds per square inch at twenty-eight days. It shall be so poured that its surface around the steel core will at all times be substantially level.

(5) The allowable load shall be computed on the basis of nine hundred pounds per square inch on the net area of

the concrete, eight thousand pounds per square inch on the steel area of the pipe and fifteen thousand pounds per square inch on the area of the steel core.

(6) The details of the installation, including inspection and cleaning of the socket, the placement of concrete under water and in the dry, the method of centering the steel core and all other phases of the work shall be submitted to the Commissioner for approval.

Section 2914. — Composite Piles.

(a) A composite pile shall consist of a combination of not more than two of any of the different types of piles provided for in this Part. The minimum dimensions and other provisions applying to each type shall be those specified herein. The connection between the two types of piles shall be constructed so as to prevent their separation, to maintain their alignment, to support the load and to be watertight where concrete must be placed subsequent to the driving. The design and the details of the connection shall be subject to the Commissioner's approval.

(b) The use of wood-composite piles shall be limited for support of buildings of Types V and VI, and for one-story buildings of other types.

(c) The center-to-center spacing shall be governed by the larger spacing, required in this Part, for the types composing the pile.

(d) The allowable load on composite piles shall be that allowed for the weaker of the two sections. For wood-composite piles the allowable load shall not exceed eighty per cent of that allowed for the wood section alone.

Section 2915. — Bearing Tests.

(a) Whenever the allowable bearing value on bearing materials or on piles is in doubt, the Commissioner may require bearing tests to be made.

(b) Before any bearing test is started, a sketch of the proposed test arrangement and an outline of the procedure to be followed shall be submitted to the Commissioner and shall have his written approval.

(c) Bearing tests shall be conducted in the presence of an inspector, qualified by experience and training, and who is satisfactory to the Commissioner. A copy of the test results obtained and a graph of the time-settlement curve for each increment of load and of

the load-settlement and rebound curve for the entire test shall be submitted to the Commissioner at the completion of each test.

(d) The load shall be applied by direct weight or by means of a newly calibrated hydraulic jack. The application of the test load shall be in steps equal to not more than one-half the contemplated design load, to twice the contemplated design load, except as provided in paragraph (g) of this section. The unloading shall be in at least two steps, to the design load and then to zero load. The contemplated design load during the loading and unloading cycles shall be maintained constant for at least twenty-four hours and until settlement or rebound does not exceed two-hundredth of an inch in twenty-four consecutive hours. The load for all other load steps including the zero load at the end of the test shall be maintained constant for a period not less than four hours. Sufficient readings for each load step shall be made to define properly the time-settlement and rebound curve.

(e) Observation of vertical movement shall be made with dial extensometers with an accuracy of at least one-thousandth of an inch. The readings shall be sufficient in number to define the time-settlement and rebound curve and shall be referred to a beam the ends of which rest on or are fixed to reliable supports located at least six feet from the center of the test. In addition, the elevation of the supports shall be checked frequently with reference to a fixed benchmark. The entire measuring set-up shall be protected against direct sunlight, frost action and other disturbances that might affect its reliability. Temperature readings, both inside and outside the test enclosure, shall be made when the vertical movements are recorded.

(f) *Additional Requirements for Soil Bearing Tests.*

(1) Soil bearing tests shall be applied to the soil at the elevations of the proposed bearing surfaces of the structure.

(2) The excavation immediately surrounding an area to be tested shall be made no deeper than one foot above the plane of application of the test, except that for material of Class 14 the test load may be applied directly on the surface. The test plate shall be placed with uniform bearing. For the duration of the test the soil surrounding the test area shall be protected effectively against evaporation and frost action.

(3) For bearing materials of Classes 1 to 5 inclusive, the loaded area shall be not less than one square foot and for other classes not less than four square feet. For bearing materials of Classes 1 to 3 inclusive, the Commissioner may permit compression tests on rock cores to be substituted for bearing tests. Each test specimen shall have a height not less than twice its diameter.

(4) The proposed design load shall be allowed provided that the requirements of section twenty-nine hundred and four are fulfilled and the settlements under the design load and twice the design load do not exceed three-eighths of an inch and one inch, respectively.

(g) *Additional Requirements for Pile-Bearing Tests.*

(1) A single pile shall be load tested to not less than twice the design load. When two or more piles are to be tested as a group, the total load shall be not less than one and one-half times the design load for the group.

(2) The design load shall not exceed the load allowed in this Part for each type of pile nor one-half of the maximum applied load provided that the load-settlement curve shows no sign of failure and provided that the permanent settlement of the top of the pile, after removal of all load at the completion of the test, does not exceed one-half inch.

Section 2916. — Settlement Analysis.

(a) Whenever a structure is to be supported by medium or soft clay (materials of Classes 11 and 12), the settlements of the structure and of neighboring structures due to consolidation of the clay shall be given careful consideration. In case one or more of the following listed conditions, or other conditions prevail that might cause similar effects, the Commissioner may require a settlement analysis to be made by a competent engineer with specialized training and experience in soil mechanics:

(1) The structure induces a net increase in stress greater than one-quarter of a ton per square foot in underlying soft clay.

(2) The structure induces a net increase in stress greater than three-quarters of a ton per square foot in underlying medium clay.
(3) The structure has substantial variations in load at foundation grade.
(4) The structure is underlain by soft clay showing large variations in thickness.

(b) A settlement analysis will be usually based on a computation of the net increase in stress, after deducting the weight of excavated soil and other loads under which the clay was fully consolidated, that will be induced by the structure, combined with soil compressibility data derived by one or more of the following means:

(1) Consolidation tests on undisturbed specimens with a diameter of at least two and one-half inches. The report shall include a description of the method of sampling and a description of the quality of the samples including representative photographs of longitudinal sections through such samples when partially dried.
(2) Use of empirical relationships between compressibility of the clay and the natural water content, the liquid and the plastic limits.
(3) A review of the settlement records and behavior of other buildings having similar subsoil profiles.

(c) Should the analysis indicate that the total or differential settlements of the structure would exceed values which would cause excessive stresses in the structure or would impair its usefulness, the design of the foundation and/or superstructure shall be modified.*

*This may be accomplished by one or a combination of the following measures:
(1) Use of a deeper basement under portions of, or over the entire building area.
(2) Increased stiffness, particularly of the foundations.
(3) Changes in the design of the building which will effect a more uniform load distribution.
(4) Changes in the design of the building which will effect a reduction in the total load and thereby in the stresses induced in the compressible soil strata.
Frequently, the use of substantially reinforced concrete girders beneath all walls are a desirable or necessary protection of those elements of a building that are most sensitive to differential settlements.