UNIVERSITY OF ILLINOIS

THE MATERIALS TESTING LABORATORY

DEDICATED MAY 2, 1930

URBANA, ILLINOIS

THE MATERIALS TESTING LABORATORY
WAS ERECTED BY
THE STATE OF ILLINOIS PURSUANT TO
THE ACT OF THE FIFTY-FIFTH
GENERAL ASSEMBLY

THE MATERIALS TESTING LABORATORY

1. *Development of Laboratory Instruction at University of Illinois.*—The University of Illinois was one of the first of the engineering colleges in the country to establish laboratories for student instruction. Laboratory instruction in materials testing was given by Professor Arthur N. Talbot in 1887 with home-made equipment, and in 1889 a Riehle 100 000-lb. testing machine was purchased. Laboratory work in cement testing was begun by Professor Ira O. Baker in 1889. The first regular laboratory instruction in hydraulics was begun by Prof. Talbot in 1893, although some volunteer work had been done by students in the early '70's under the direction of Professor S. W. Robinson.

The facilities for laboratory instruction and research in the testing of materials were greatly increased by the construction of the Laboratory of Applied Mechanics in 1902. In 1907 a bay in the mechanical engineering laboratory was assigned to research in cement and concrete, and in 1915 the completion of the Ceramics Building made space available for a Highway Laboratory. The growing enrollment of students and the increasing number of projects of the Engineering Experiment Station soon overtaxed the laboratory facilities, and it was necessary to utilize the old boiler house for the cement laboratory, a structural laboratory, and a fatigue of metals laboratory, and a portion of the Ceramics Building for research work in concrete and reinforced concrete. The serious congestion in all of the laboratories of the engineering college finally led, in 1927, to the appropriation by the Legislature of $500 000 for a Materials Testing Laboratory and equipment. The new building has not only increased the facilities and space for the work in materials testing, but has also released space for the laboratories in electrical, mechanical, and ceramic engineering.

2. *The Materials Testing Laboratory.*—The new Materials Testing Laboratory is a four-story brick building of a modified Georgian design. It is located in the Engineering group between Burrill Avenue and Wright Street. The plan is in the form of an H with two wings 187 by 50 feet and a stem 110 by 92 feet. The building contains the laboratories of the departments of Civil Engineering and Theoretical and Applied Mechanics, and a number of offices and class rooms.

MATERIALS TESTING LABORATORY (LOOKING NORTHEAST FROM WRIGHT STREET)

The building has a structural steel frame, reinforced concrete floors, and partition walls of Haydite concrete block. It is fireproof throughout.

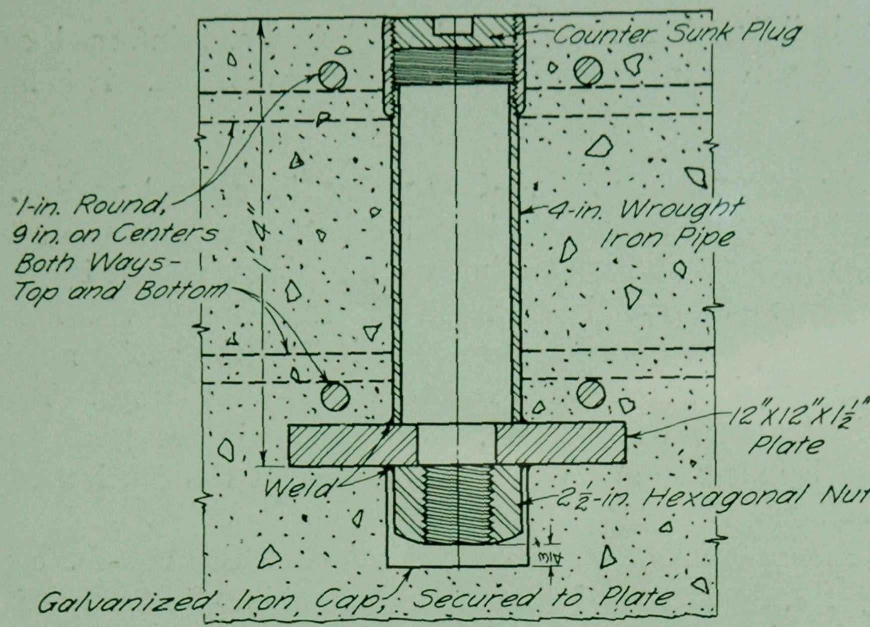
3. *The Large Crane Bay.*—Occupying the central portion of the building to its full height is the large laboratory, a room 40 by 147 feet in plan, where the heavy testing work is done, served by a 10-ton traveling crane 50 feet above the floor. The room is well lighted by steel sash windows covering the upper half of the entire north wall, and by an overhead system of fourteen 1000-watt lamps. The floor, at the basement level of the building, is made accessible to truck deliveries by a ramp and large service door at the south side of the building.

An Emery-Tatnall testing machine of 3 000 000-lb. capacity, built by the Southwark Foundry and Machine Company of Philadelphia, has been installed. This machine, which ranks among the largest in the world, has a clear working space of 7 feet 6 inches between screws, and will accommodate tension or compression test pieces up to a length of 38½ feet. The machine extends 15 feet below the floor and 49½ feet above it. It may be used in testing full-sized steel and concrete columns, masonry piers, steel cables, riveted and welded joints, eye-bars, car couplers, chord members of bridges, and other heavy structural members.

The crane bay also contains a 600 000-lb. Riehle testing machine which can take tension or compression test pieces of lengths up to 25 feet, a 300 000-lb. Riehle universal testing machine accommodating test pieces to a height of 20 feet, a 200 000-lb. Olsen universal testing machine, a 230 000-in.-lb. Olsen torsion testing machine, and a Turner impact testing machine.

It may be of interest to note that the 200 000-lb. testing machine referred to, purchased in 1894, was used in Professor Talbot's pioneer investigations of concrete and reinforced concrete.

An unusual facility has been provided by making a part of the floor a heavily reinforced concrete slab 16 inches thick, which will serve as a testing base. Steel inserts, each capable of withstanding an upward pull of 50 000 pounds are placed in the slab in rows 6 feet apart in both directions. With this provision, a test structure, such as a reinforced concrete arch, may be built on the testing base and a testing frame built around it through which loads can be applied to the structure by means of hydraulic jacks or similar apparatus. The heavy section of the floor is 23½ by 120 feet in plan and contains 80 inserts. A detail of an insert is shown on page 6.



INSERT ANCHOR

4. *The Small Crane Bay.*—Adjacent to the large crane bay, and connected to it by a large doorway is a two-story bay, 23 feet wide and 112 feet long, which is used for the preparation of specimens and testing. This is served by a 6-ton traveling crane, and is a part of the concrete and the structural research laboratories described in the following paragraphs. A part of the floor is of reinforced concrete 12 inches thick, and provided with 42 inserts similar to those in the large crane bay. These are placed at 3-foot intervals in rows 4 feet apart, and each will withstand a 10 000-lb. pull. A 300 000-lb. Olsen universal testing machine with a 22-ft. table is used for testing reinforced concrete beams and slabs.

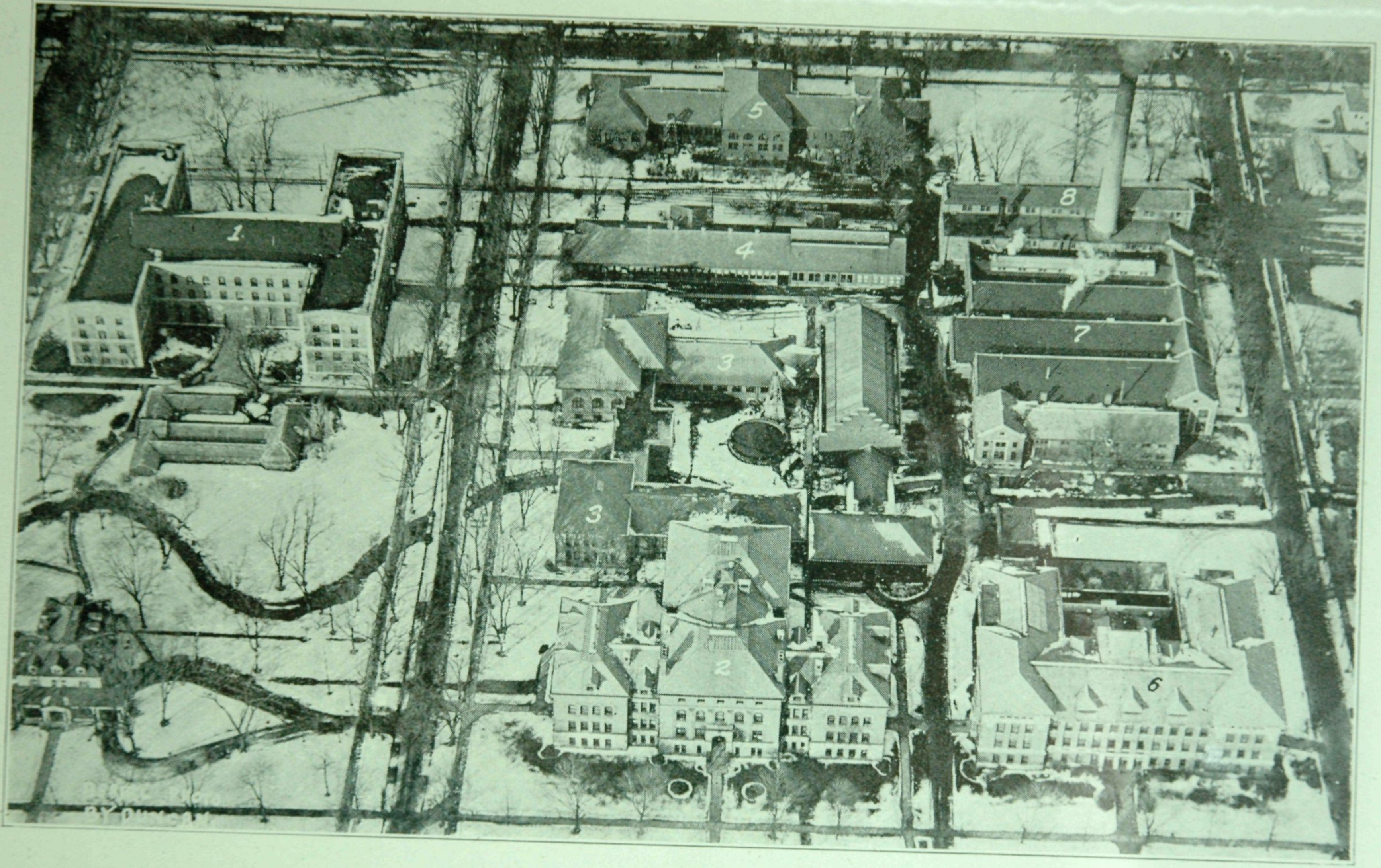
5. *Concrete Research Laboratory.*—This laboratory occupies a part of the small crane bay and the southeast wing of the basement. It contains storage space for concrete materials and reinforcing steel, concrete mixers, a concrete saw, a core drill, and other tools and equipment used in fabricating and testing members of plain and reinforced concrete. Large moist rooms with temperature control provide standard curing conditions for test pieces. Similar moist rooms are provided in the structural and highway laboratories, there being seven in all. On the first floor are located rooms for cement storage, drying, and for tests of cement, aggregates, and mortar.

6. *Structural Research Laboratory.*—The structural research laboratory occupies the west half of both the large and the small crane

MATERIALS TESTING LABORATORY—EAST FRONT

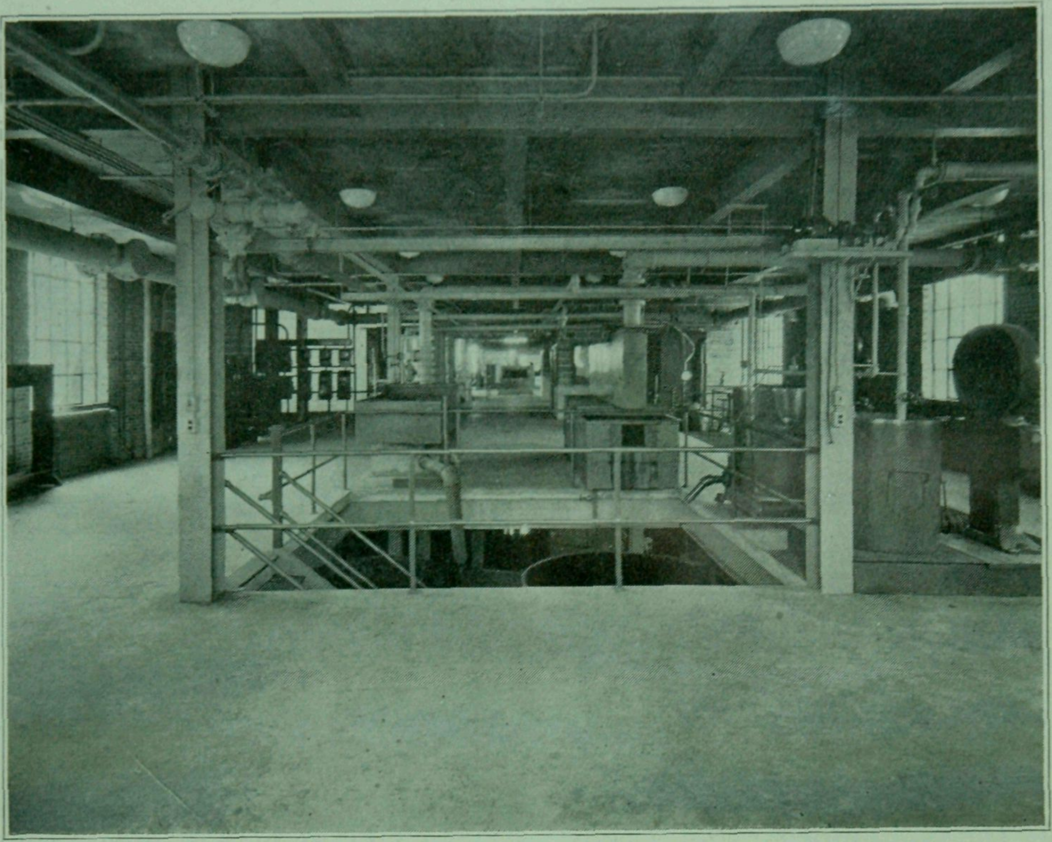
bays. As its name implies, this laboratory is designed primarily to study the behavior of structures, as distinguished from a determination of the physical characteristics of engineering materials. The large crane bay is equipped with heavy machines for testing large structures and structural members. As far as possible the concrete specimens will be poured and the steel specimens manufactured and fabricated in the small crane bay. Sand and gravel bins opening off the southwest corner of the small crane bay provide storage for materials. Two moist rooms having automatic temperature and moisture control are located at the west end of the bay. These rooms are also used for experimental work requiring freedom from temperature changes and air currents. The machine shop serving the structural research laboratory is adjacent to the large crane bay, making it possible to manufacture, handle, and test large structures and structural parts.

7. *Student Concrete Laboratory.*—This laboratory occupies the basement of the northeast wing, with auxiliary rooms available immediately above on the first floor. It is used mainly for the instruc-



THE ENGINEERING GROUP

1—Materials Testing Laboratory. 2—Engineering Hall. 3—Electrical Engineering Laboratory. 4—Metal Shop. 5—Wood Shop. 6—Physics Laboratory. 7—Mechanical Engineering Laboratory. 8—Power Plant.



HYDRAULICS LABORATORY

tion of students in the testing of the materials of concrete and of concrete itself. Three moist rooms for the curing of concrete specimens are located along the south side of the room. Four large storage bins for materials are located outside the building on the north, with access through the north wall.

The equipment in this laboratory includes student work tables, cement testing machines, steam bath, moist closet, balances, sieve shaker, gyratory riddle, materials bins, drying oven, 200 000-lb. hydraulic compression testing machine, field concrete-beam-testing machine, flow-table, refrigeration unit, recording thermometers, concrete mixers, and miscellaneous apparatus and equipment. A Talbot-Jones rattler for testing the wearing qualities of concrete is located in a sound-proof room in the basement.

8. *Hydraulics Laboratory.*—The hydraulics laboratory occupies the basement and first floor of the west wing. There are several large concrete channels in the basement which may be used both for hydraulic experiments, and to receive water discharged from apparatus on the first floor. One of these channels is 5 by 5 feet in cross-section

and 175 feet long. Another is 6 feet wide and has a depth of 18 feet for a distance of 24 feet, 13.5 feet for a distance of 59 feet, then changes to a weir section 10 feet deep and 37 feet long. In this channel it will be possible to make tests involving discharges up to 45 cubic feet per second.

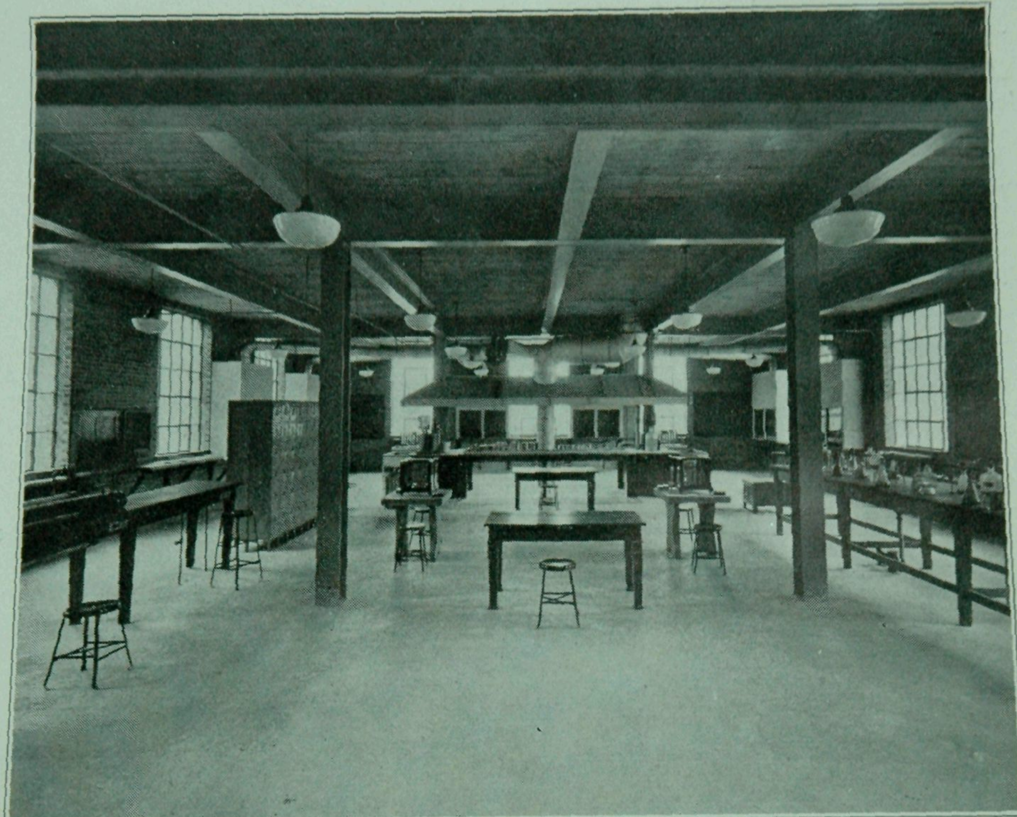
The pumping equipment includes a 500-gal.-per-min. vertical motor-driven sump pump, a pair of 1000-gal.-per-min. motor-driven centrifugal pumps arranged for parallel or for series operation, and a pair of 2000-gal.-per-min. pumps similarly connected. All of these pumps operate against a maximum head of 80 feet when used singly or in parallel, and against a head of 160 feet when connected in series. The pumps discharge into a piping system consisting of four lines of 12-in. pipe serving all parts of the laboratory. There is also a pump having a capacity of 30 cu. ft. per sec. (13 500 gal. per min.) against a head of 40 feet, direct connected to a 200-horse power, 2300-volt, synchronous motor. The pump discharges into a 24-in. spirally-riveted steel pipe line. The water used in the laboratory is recirculated through pits having a storage capacity of about 90 000 gallons.

A standpipe 6 feet in diameter and 60 feet high is located in one corner of the hydraulics laboratory. Four overflow weirs are provided in the standpipe so that a constant head may be held at one of four levels. Since each weir is nearly 16 feet long, the head will be held within a few inches of a constant level under any condition of operation.

The main upper floor of the hydraulics laboratory contains weirs, orifice tanks, meter testing equipment, venturi meters, a three-stage centrifugal pump capable of delivering 300 gal. per min. against a 460-ft. head, impulse water wheels, motor-driven centrifugal pumps, a 50-horse power motor-generator set, a hydraulic ram, a glass-encased turbine, and other apparatus for general student laboratory work.

By means of openings in the floor, covered by removable steel gratings, the water used in experiments may be discharged into steel tanks of various sizes in the basement for measurement or direct weighing on platform scales.

9. *Applied Mechanics Laboratory.*—The Applied Mechanics Laboratory occupies the second floor of the west wing of the building, and is used for the instruction of students. It contains nine testing machines with capacities of from 50 000 to 200 000 pounds, equipped with individual motor drives. In addition there are a number of smaller hand-operated beam-testing machines, torsion machines, a

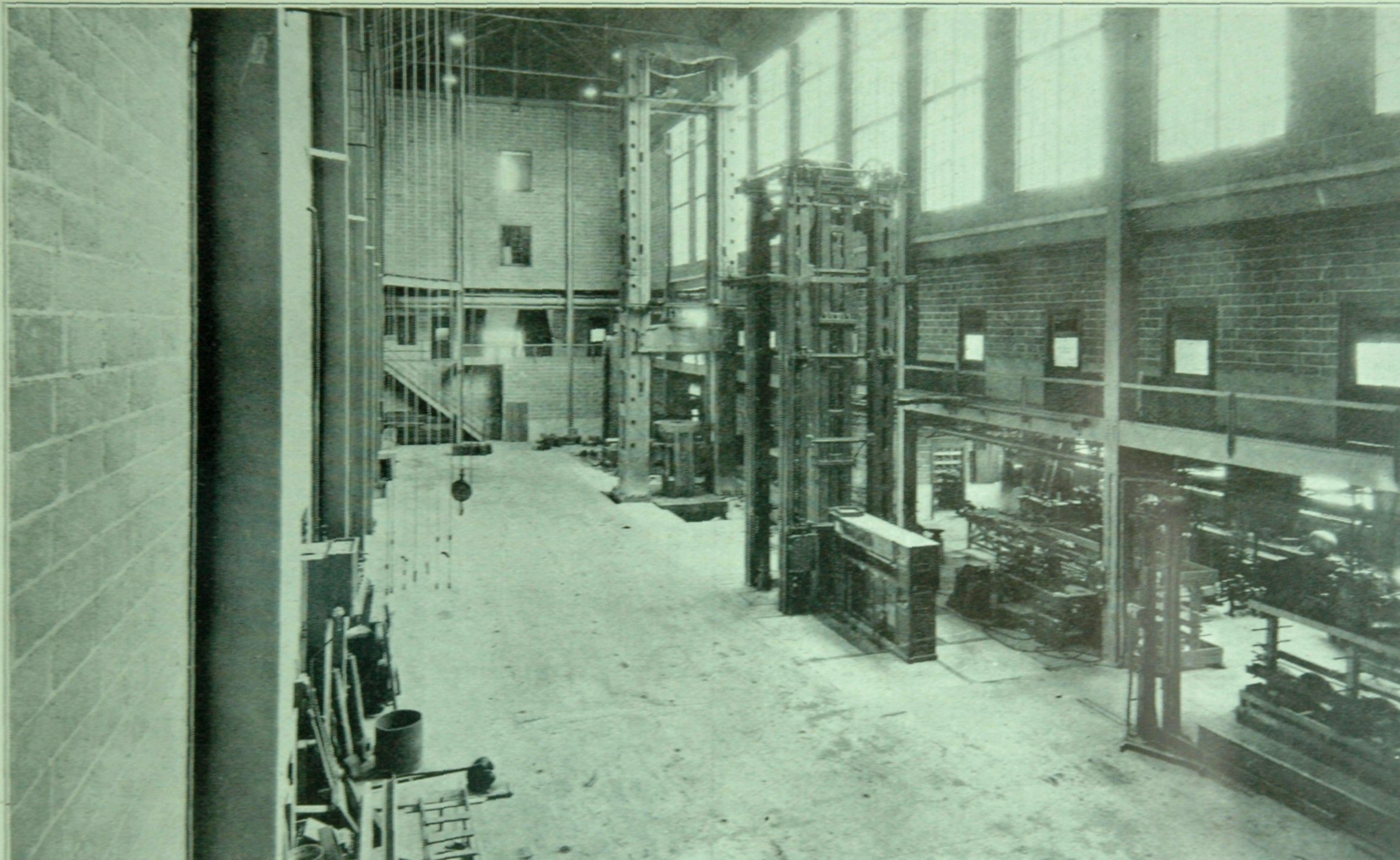


BITUMINOUS LABORATORY

special Olsen impact machine, several motor-driven testing machines of various types for testing small specimens, hardness testing machines, and various types of strain measuring apparatus.

10. *Highway Laboratories.*—The highway laboratories occupy the second floor of the east wing, with auxiliary rooms available on the first floor in the northeast wing, and are used for the instruction of students. The elementary bituminous laboratory occupies the northeast wing on the second floor and contains a large work table with ventilated hood, a filtration table with 16 suction pumps, a centrifugal extraction machine for the examination of bituminous mixtures, a ductility machine, a rotary shelf oven, and several smaller ovens, a constant-temperature water bath, asphalt penetration machines, eight analytical balances, specific gravity apparatus, Engler viscosimeters, etc. Small equipment is kept in 150 12-inch cubical lockers.

The advanced bituminous laboratory is at the south end of the east wing on the second floor, and is equipped with six ventilated compartments, constant high temperature oven, centrifuge, centrifugal extraction machine for the examination of bituminous materials, chemical desk, and miscellaneous small equipment.



THE LARGE CRANE BAY

FATIGUE OF METALS LABORATORY

The stone testing equipment occupies other rooms in the southeast wing, and consists of two drill presses with diamond-set core drills for drilling 1-inch and 2-inch cores, a high-speed abrasive cut-off saw, a Weaver forcing press for preparing abrasion test specimens, a ball mill, a briquet molding machine, a Page impact machine for cementation, a Page impact machine for toughness, a Deval abrasion machine, a Dorry machine for hardness, ovens, pan racks, a Ro-tap sieve shaker, balances, and miscellaneous small equipment.

The brick rattler for testing the quality of paving brick is located in the basement in the same room as the Talbot-Jones rattler.

11. *Fatigue of Metals Laboratory.*—This laboratory occupies the third story of the northwest wing of the building, and is devoted to the study of the behavior of metals under repeated loading. The laboratory equipment includes the following machines for testing of metals under fatigue loading:

Twenty-one rotating-beam machines, three of them of large size, and one capable of testing car-axle specimens 2 inches in diameter; three machines for testing metals under repeated twisting stress; three machines for testing metals under repeated tensile loading; two machines for testing sheet metal under repeated bending; and six machines for testing metal in a stationary specimen under repeated bending, three of which are arranged to test the metal at elevated temperatures. Many of these machines were designed by the staff of the laboratory and constructed in the laboratory shop.

In addition to these machines there is a 100 000-lb. Amsler testing machine, a machine designed in the laboratory for testing sheet metal, and machines for hardness and impact tests of metals. There is also a gas furnace for heat treating, and case carburizing and nitriding of specimens.

Many metals have been subjected to fatigue tests, among them being carbon steels of various grades, spring steels, alloy steels used in the automotive industry, Armco iron, aluminum, copper, brass and bronzes, monel metal, cast iron, and various alloys of copper, nickel and chromium. Tests of parts, such as car axles and turbine blades, have also been made.

The fatigue machines are all arranged to operate continuously day and night when necessary; the longest test which has yet been made in the laboratory involved 400 days of continued service with about $1\frac{1}{4}$ billion reversals of stress.

12. *Machine Shops.*—Space for two well-equipped shops is provided in the building. The shop for the structural research laboratory is conveniently located in the basement, adjacent to the large crane bay. The shop for the research and student laboratories in Theoretical and Applied Mechanics is located in the southwest wing on the third floor. Four mechanicians are employed in making specimens for research investigations and for student tests, in constructing apparatus, and in keeping the equipment of all laboratories in repair.

Delivery of heavy articles to the third-floor shop is by a large freight elevator, and by the 10-ton crane. A portable landing platform in one corner of the crane bay allows the crane to deposit its load at any floor level.

13. *Calibration Room.*—In the calibration room are kept the accurate standards of length and weight, with the necessary apparatus for calibrating and standardizing the ordinary equipment of the laboratory. A set of Johannsen blocks and auxiliary tools, and a special calibrating apparatus may be used in checking and calibrating extensometers and strain gages. A precise Sealers Balance and an analytical balance, together with a set of Class A standard weights

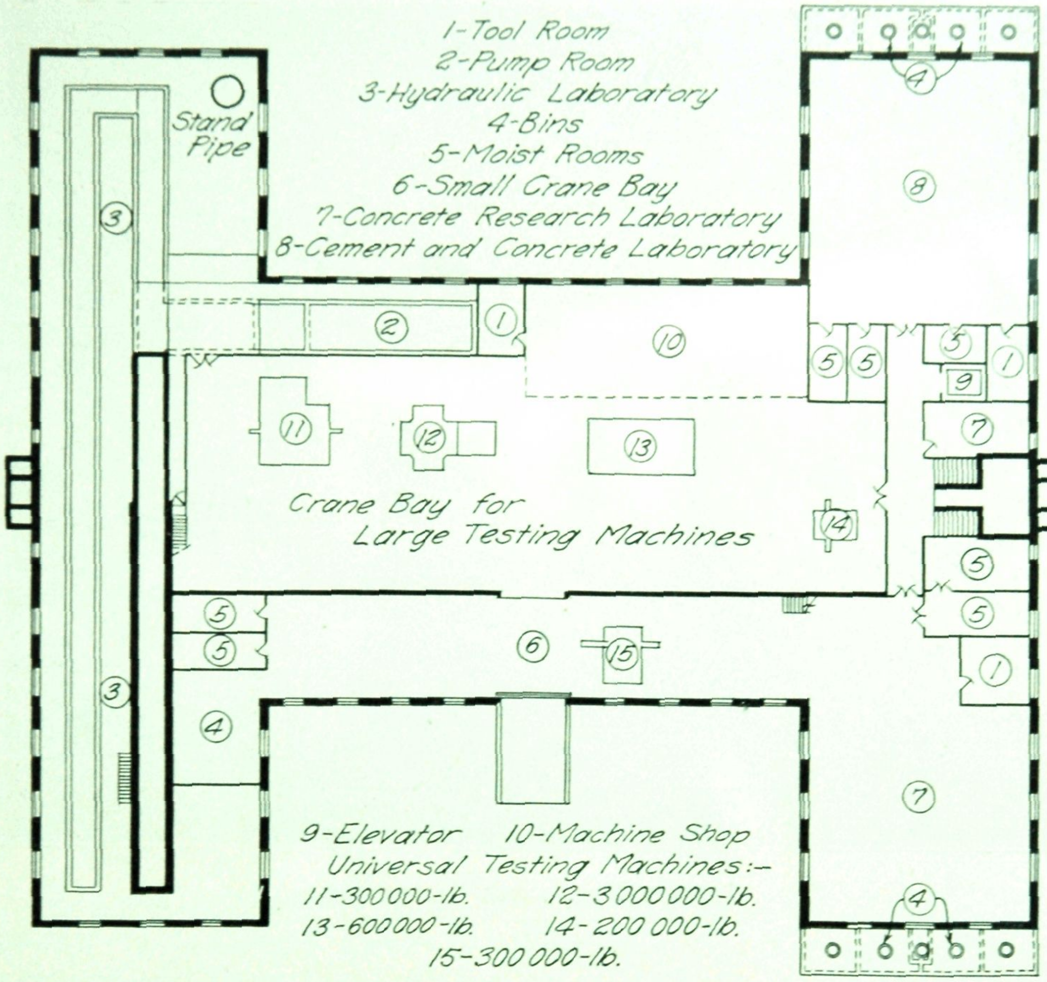
APPLIED MECHANICS LABORATORY

certified by the U. S. Bureau of Standards, permit the standardization of dead weights up to 50 pounds. A Crosby fluid pressure scales is used as a standard of reference for pressure gages of capacities up to 10 000 lb. per sq. in. An Amsler standardizing box of 100 000-lb. capacity is provided for use in checking the accuracy of testing machines in the various laboratories.

14. *Miscellaneous Laboratories.*—Among the smaller laboratories is a large dark room provided with apparatus for the investigation of stresses in transparent models by means of polarized light.

In another room a considerable amount of equipment has been provided for experimental work in the line of recent developments in soil mechanics.

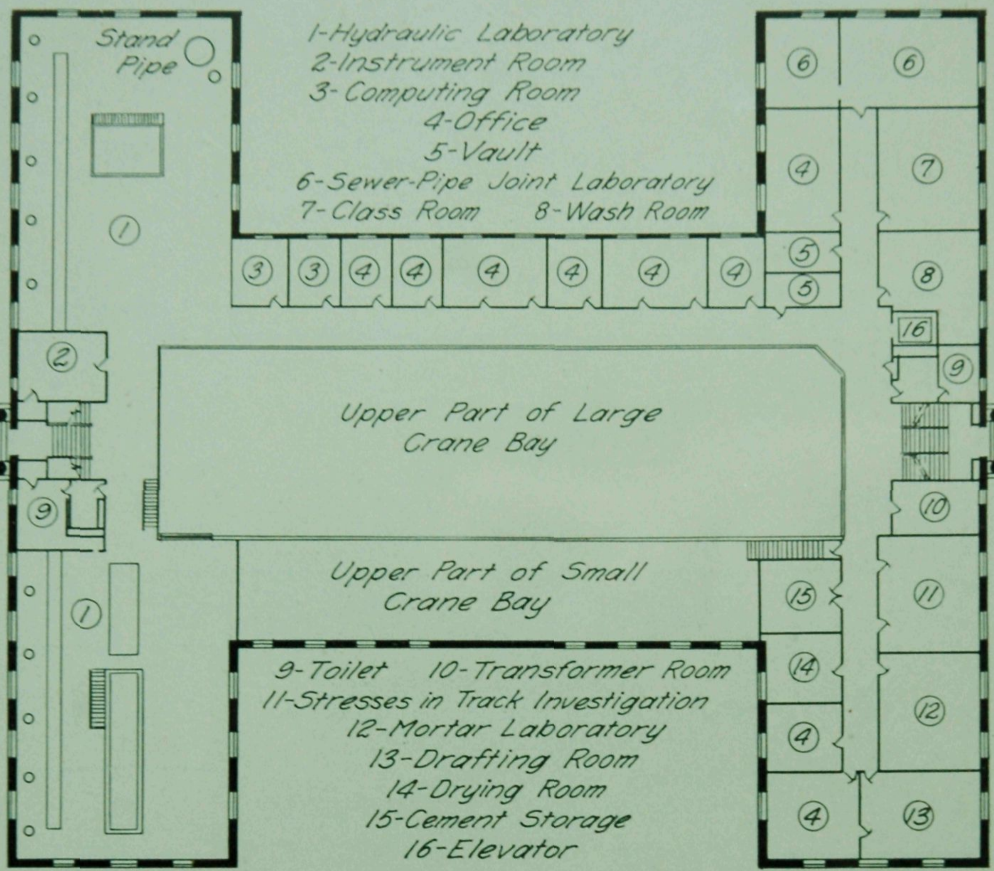
In other rooms space is provided for tests of flow of lead under continued loading, of shrinkage and flow of reinforced concrete columns under a load which will be continuously applied for a period of one year, and apparatus for determining shearing stresses in noncircular sections subjected to torsion by means of the soap film analogy.



Basement Floor Plan

15. *Miscellaneous Rooms.*—In addition to the laboratories there are offices in the building accommodating thirty-five members of the teaching and research staff. The general office of the Theoretical and Applied Mechanics department is in this building. A conference room is provided for department and committee meetings. There are five class rooms, five computing rooms and two instrument rooms used for student work. Two fireproof vaults are used to store department records and experimental data.

16. *Facilities for Coöperative Investigations.*—The various research laboratories of the building are used for both the research projects of the Engineering Experiment Station, and for special coöperative investigations financed by organizations outside the University. There are at present 16 coöperative investigations in progress in the building. The following list of the titles of these investigations gives an idea of the scope of the work:



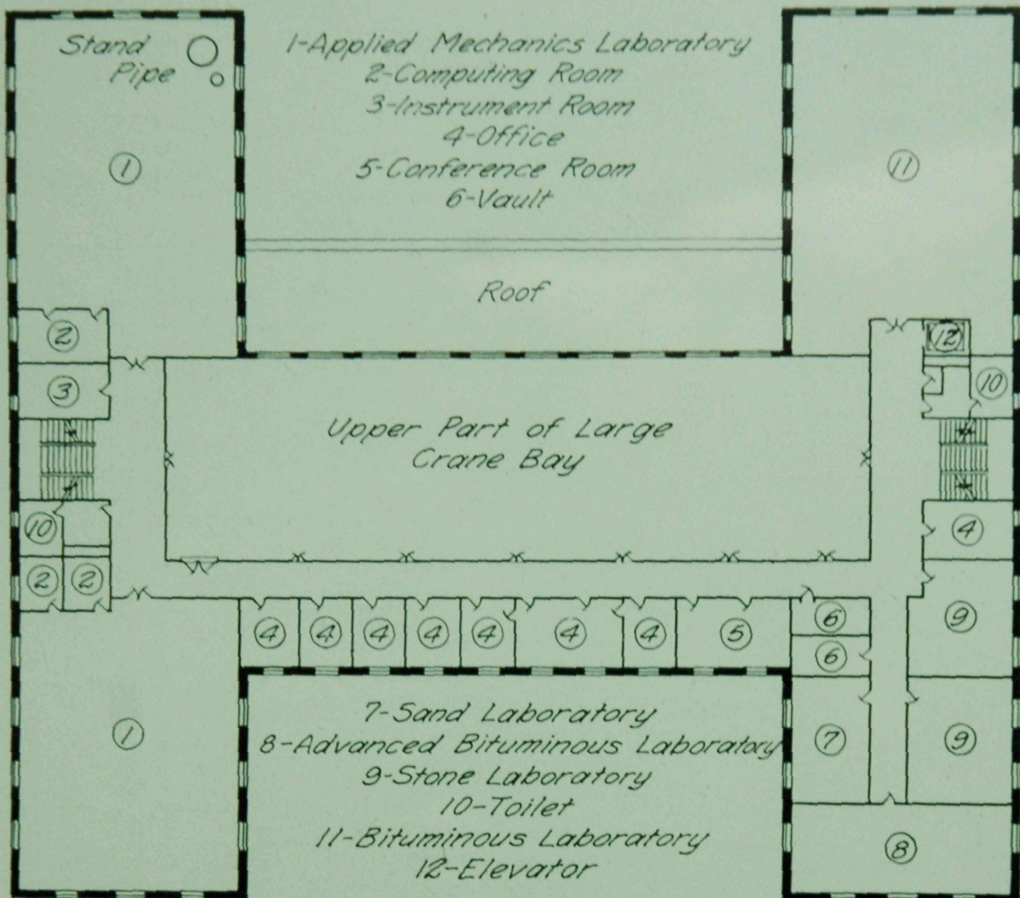
FIRST FLOOR PLAN

(1) Stresses in railroad track, in coöperation with The American Society of Civil Engineers and the American Railway Engineering Association.

(2) The fatigue phenomena of metals, in coöperation with the Engineering Foundation, the National Research Council, the General Electric Company, the Allis-Chalmers Manufacturing Company, the Copper and Brass Research Association, and the Western Electric Company.

(3) Cast iron pipe, in coöperation with the Sectional Committee on Specifications for Cast Iron Pipe, organized under the procedure of the American Engineering Standards Association with the American Gas Association, American Society for Testing Materials, American Water Works Association, and New England Water Works Association as sponsor societies.

(4) Car axle failures, in coöperation with the Utilities Research Commission. The Utilities Research Commission is composed of representatives of the following public utilities companies which



SECOND FLOOR PLAN

supply the funds for the investigation: Commonwealth Edison Company, Peoples Gas, Light and Coke Company, the Public Service Company of Northern Illinois, the Middle West Utilities Company, the Chicago Rapid Transit Company, the Chicago North Shore and Milwaukee Railroad Company, and the Northern Indiana Public Service Company.

(5) Impact in elevated steel railway structures, in coöperation with the Utilities Research Commission.

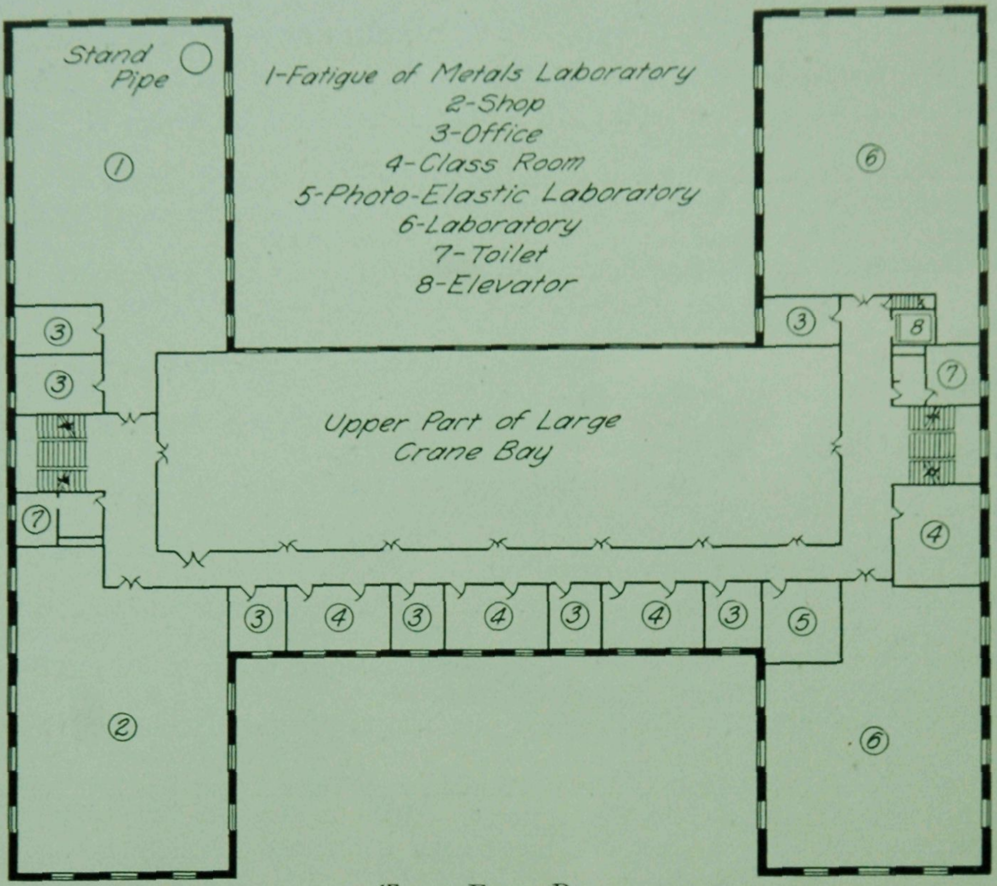
(6) Fissures in steel rails, in coöperation with the Utilities Research Commission.

(7) Methods to eliminate stretching of lead sheaths of high voltage cables, in coöperation with the Utilities Research Commission.

(8) Large steel rollers, in coöperation with the American Railway Engineering Association.

(9) Biaxial stresses, in coöperation with the Chicago Bridge and Iron Works.

(10) Riveted connections, in coöperation with the Chicago Bridge and Iron Works.



THIRD FLOOR PLAN

(11) Reinforced concrete arches, in coöperation with the American Society of Civil Engineers.

(12) Clay sewer pipe, in coöperation with the Clay Products Association.

(13) Jointing materials for clay sewer pipe, in coöperation with the Clay Products Association.

(14) Fatigue tests of metals at elevated temperatures, in coöperation with the Joint Research Committee on the Effect of Temperature on the Properties of Metals, organized by the American Society for Testing Materials and the American Society of Mechanical Engineers.

(15) Concrete made with light aggregate, in coöperation with the Western Brick Company, Danville, Ill.

(16) Reinforced concrete columns, in coöperation with The American Concrete Institute.

17. *Bulletins and Circulars Relating to Engineering Materials, Design, and Hydraulics.*—The results of investigations in the field of

engineering materials, design, and hydraulics have been recorded in the following bulletins and circulars:

Bulletin No. 1. Tests of Reinforced Concrete Beams, by Arthur N. Talbot. 1904.

Circular No. 2. Drainage of Earth Roads, by Ira O. Baker. 1906.

Bulletin No. 4. Tests of Reinforced Concrete Beams, Series of 1905, by Arthur N. Talbot. 1906.

Bulletin No. 6. Holding Power of Railroad Spikes, by Roy I. Webber. 1906.

Bulletin No. 8. Tests of Concrete: I, Shear; II, Bond, by Arthur N. Talbot. 1906.

Bulletin No. 10. Tests of Concrete and Reinforced Concrete Columns, Series of 1906, by Arthur N. Talbot. 1907.

Bulletin No. 12. Tests of Reinforced Concrete T-Beams, Series of 1906, by Arthur N. Talbot. 1907.

Bulletin No. 14. Tests of Reinforced Concrete Beams, Series of 1906, by Arthur N. Talbot. 1907.

Bulletin No. 18. The Strength of Chain Links, by G. A. Goodenough and L. E. Moore. 1907.

Bulletin No. 20. Tests of Concrete and Reinforced Concrete Columns, Series of 1907, by Arthur N. Talbot. 1907.

Bulletin No. 22. Test of Cast-Iron and Reinforced Concrete Culvert Pipe, by Arthur N. Talbot. 1908. Reprinted, 1926.

Bulletin No. 23. Voids, Settlement, and Weight of Crushed Stone, by Ira O. Baker. 1908.

Bulletin No. 27. Tests of Brick Columns and Terra Cotta Block Columns, by Arthur N. Talbot and Duff A. Abrams. 1908.

Bulletin No. 28. A Test of Three Large Reinforced Concrete Beams, by Arthur N. Talbot. 1908.

Bulletin No. 29. Tests of Reinforced Concrete Beams: Resistance to Web Stresses, Series of 1907 and 1908, by Arthur N. Talbot. 1909.

Bulletin No. 41. Tests of Timber Beams, by Arthur N. Talbot. 1909.

Bulletin No. 42. The Effect of Keyways on the Strength of Shafts, by Herbert F. Moore. 1909.

Bulletin No. 44. An Investigation of Built-up Columns under Load, by Arthur N. Talbot and Herbert F. Moore. 1910.

Bulletin No. 45. The Strength of Oxyacetylene Welds in Steel, by Herbert L. Whittemore. 1910.

Bulletin No. 48. Resistance to Flow through Locomotive Water Columns, by Arthur N. Talbot and Melvin L. Enger. 1911.

Bulletin No. 49. Tests of Nickel-Steel Riveted Joints, by Arthur N. Talbot and Herbert F. Moore. 1911.

Bulletin No. 52. An Investigation of the Strength of Rolled Zinc, by Herbert F. Moore. 1911.

Bulletin No. 56. Tests of Columns: An Investigation of the Value of Concrete as Reinforcement for Structural Steel Columns, by Arthur N. Talbot and Arthur R. Lord. 1912.

Bulletin No. 64. Tests of Reinforced Concrete Buildings under Load, by Arthur N. Talbot and Willis A. Slater. 1913.

Bulletin No. 67. Reinforced Concrete Wall Footings and Column Footings, by Arthur N. Talbot. 1913. Reprinted, 1925.

Bulletin No. 68. The Strength of I-Beams in Flexure, by Herbert F. Moore. 1913.

Bulletin No. 70. The Mortar-Making Qualities of Illinois Sands, by C. C. Wiley. 1913.

Bulletin No. 71. Tests of Bond between Concrete and Steel, by Duff A. Abrams. 1913.

Bulletin No. 80. Wind Stresses in the Steel Frames of Office Buildings, by W. M. Wilson and G. A. Maney. 1915.

Bulletin No. 81. Influence of Temperature on the Strength of Concrete, by A. B. McDaniel. 1915.

Bulletin No. 84. Tests of Reinforced Concrete Flat Slab Structures, by Arthur N. Talbot and W. A. Slater. 1916.

Bulletin No. 85. The Strength and Stiffness of Steel under Biaxial Loading, by A. J. Becker. 1916.

Bulletin No. 86. The Strength of Webs of I-Beams and Girders, by Herbert F. Moore and W. M. Wilson. 1916.

Bulletin No. 96. The Effect of Mouthpieces on the Flow of Water through a Submerged Short Pipe, by Fred B. Seely. 1917.

Bulletin No. 98. Tests of Oxyacetylene Welded Joints in Steel Plates, by Herbert F. Moore. 1917.

Bulletin No. 104. Tests to Determine the Rigidity of Riveted Joints of Steel Structures, by W. M. Wilson and H. F. Moore. 1917.

Bulletin No. 105. Hydraulic Experiments with Valves, Orifices, Hose, Nozzles, and Orifice Buckets, by Arthur N. Talbot, Fred B. Seely, Virgil R. Fleming, and Melvin L. Enger. 1918.

Bulletin No. 106. Test of a Flat Slab Floor of the Western Newspaper Union Building, by Arthur N. Talbot and Harrison F. Gonnerman. 1918.

Bulletin No. 107. Analysis and Tests of Rigidly Connected Reinforced Concrete Frames, by Mikishi Abe. 1918.

Bulletin No. 108. Analysis of Statically Indeterminate Structures by the Slope Deflection Method, by W. M. Wilson, F. E. Richart, and Camillo Weiss. 1918.

Bulletin No. 109. The Orifice as a Means of Measuring Flow of Water through a Pipe, by R. E. Davis and H. H. Jordan. 1918.

Bulletin No. 115. The Relation between the Elastic Strengths of Steel in Tension, Compression, and Shear, by F. B. Seely and W. J. Putnam. 1919.

Bulletin No. 123. Studies on Cooling of Fresh Concrete in Freezing Weather, by Tokujiro Yoshida. 1921.

Bulletin No. 124. An Investigation of the Fatigue of Metals, by H. F. Moore and J. B. Kommers. 1921.

Bulletin No. 126. A Study of the Effect of Moisture Content upon the Expansion and Contraction of Plain and Reinforced Concrete, by T. Matsumoto. 1921.

Circular No. 10. The Grading of Earth Roads, by W. M. Wilson. 1923.

Bulletin No. 136. An Investigation of the Fatigue of Metals, Series of 1922, by H. F. Moore and T. M. Jasper. 1923.

Bulletin No. 137. The Strength of Concrete: Its Relation to the Cement, Aggregates, and Water, by Arthur N. Talbot and Frank E. Richart. 1923.

Bulletin No. 142. An Investigation of the Fatigue of Metals, Series of 1923, by H. F. Moore and T. M. Jasper. 1924.

Bulletin No. 143. Tests on the Hydraulics and Pneumatics of House Plumbing, by H. E. Babbitt. 1924.

Circular No. 11. The Oiling of Earth Roads, by W. M. Wilson. 1924.

Bulletin No. 152. An Investigation of the Fatigue of Metals, Series of 1925, by H. F. Moore and T. M. Jasper. 1925.

Bulletin No. 156. Tests of the Fatigue Strength of Cast Steel, by Herbert F. Moore. 1926.

Bulletin No. 162. Tests on the Bearing Value of Large Rollers, by Wilbur M. Wilson. 1927.

Bulletin No. 164. Tests of the Fatigue Strength of Cast Iron, by Herbert F. Moore, Stuart W. Lyon, and Norman P. Inglis. 1927.

Bulletin No. 165. A Study of Fatigue Cracks in Car Axles, by Herbert F. Moore. 1927.

Bulletin No. 166. An Investigation of Web Stresses in Reinforced Concrete Beams, by Frank E. Richart. 1927.

Circular No. 16. A Simple Method of Determining Stress in Curved Flexural Members, by Benjamin J. Wilson and John F. Quereau. 1927.

Bulletin No. 174. The Effect of Climatic Changes on a Multiple Span Reinforced Concrete Arch Bridge, by Wilbur M. Wilson. 1927.

Bulletin No. 175. An Investigation of Web Stresses in Reinforced Concrete Beams, Part II, Restrained Beams, by Frank E. Richart and Louis J. Larson. 1928.

Bulletin No. 176. A Metallographic Study of the Path of Fatigue Failure in Copper, by Herbert F. Moore and Frank C. Howard. 1928.

Bulletin No. 178. Tests on the Hydraulics and Pneumatics of House Plumbing, Part II, by Harold E. Babbitt. 1928.

Bulletin No. 183. Tests of the Fatigue Strength of Steam Turbine Blade Shapes, by Herbert F. Moore, Stuart W. Lyon, and Norville J. Alleman. 1928.

Bulletin No. 185. A Study of the Failure of Concrete under Combined Compressive Stresses, by Frank E. Richart, Anton Brandtzaeg, and Rex L. Brown. 1928.

Bulletin No. 190. The Failure of Plain and Spirally Reinforced Concrete in Compression, by Frank E. Richart, Anton Brandtzaeg, and Rex L. Brown. 1929.

Bulletin No. 191. Rolling Tests of Plates, by Wilbur M. Wilson. 1929.

Bulletin No. 195. The Plaster-Model Method of Determining Stresses Applied to Curved Beams, by Fred B. Seely and Richard V. James. 1929.

Bulletin No. 197. A Study of Fatigue Cracks in Car Axles, Part II, by Herbert F. Moore, Stuart W. Lyon, and Norville J. Alleman. 1929.

Bulletin No. 198. Results of Tests on Sewage Treatment, by Harold E. Babbitt and Harry E. Schlenz. 1929.

Bulletin No. 202. Laboratory Tests of Reinforced Concrete Arch Ribs, by Wilbur M. Wilson. 1929.

Bulletin No. 203. Dependability of the Theory of Concrete Arches, by Hardy Cross. 1929.

Bulletin No. 205. A Study of the Ikeda Short-Time (Electrical Resistance) Test for Fatigue Strength of Metals, by Herbert F. Moore and Seichi Konzo. 1930.

IN PRESS

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Bulletin No. 211. The Torsional Effect of Transverse Bending Load on Channel Beams, by Fred B. Seely, William J. Putnam, and William L. Schwalbe.

18. *Graduate Work.*—Engineering students who are equipped to profit by graduate work are finding that advanced training is of great value in attacking the many important technical problems that are arising in industry and engineering practice.

The graduate student through his work in the Materials Testing Laboratory comes in contact with many important experimental and analytical investigations in structural, hydraulic and highway engineering, in concrete and reinforced concrete, in fatigue of metals, and in mechanics of materials.

Of still greater value to the graduate student is his close association with highly trained specialists in experimental and analytical engineering work, and his use of the excellent laboratory equipment and facilities.

Already the work of the materials, structural, and hydraulic laboratories has attracted a considerable number of outstanding graduate students both from this country and from abroad. The demand for men specially trained in these fields of engineering is greater than the supply.