REINFORCED-CONCRETE BEAMS

Comparison of Theoretical Design with Experimental Results

By Prof. GAETANO LANZA, M. I. T.

M.I.T. sample

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IN THE NEXT ISSUE

THE CONSTRUCTION OF CHEMICAL LABORATORIES

By AUGUSTUS H. GILL, Professor of Technical Chemical Analysis, M. I. T.

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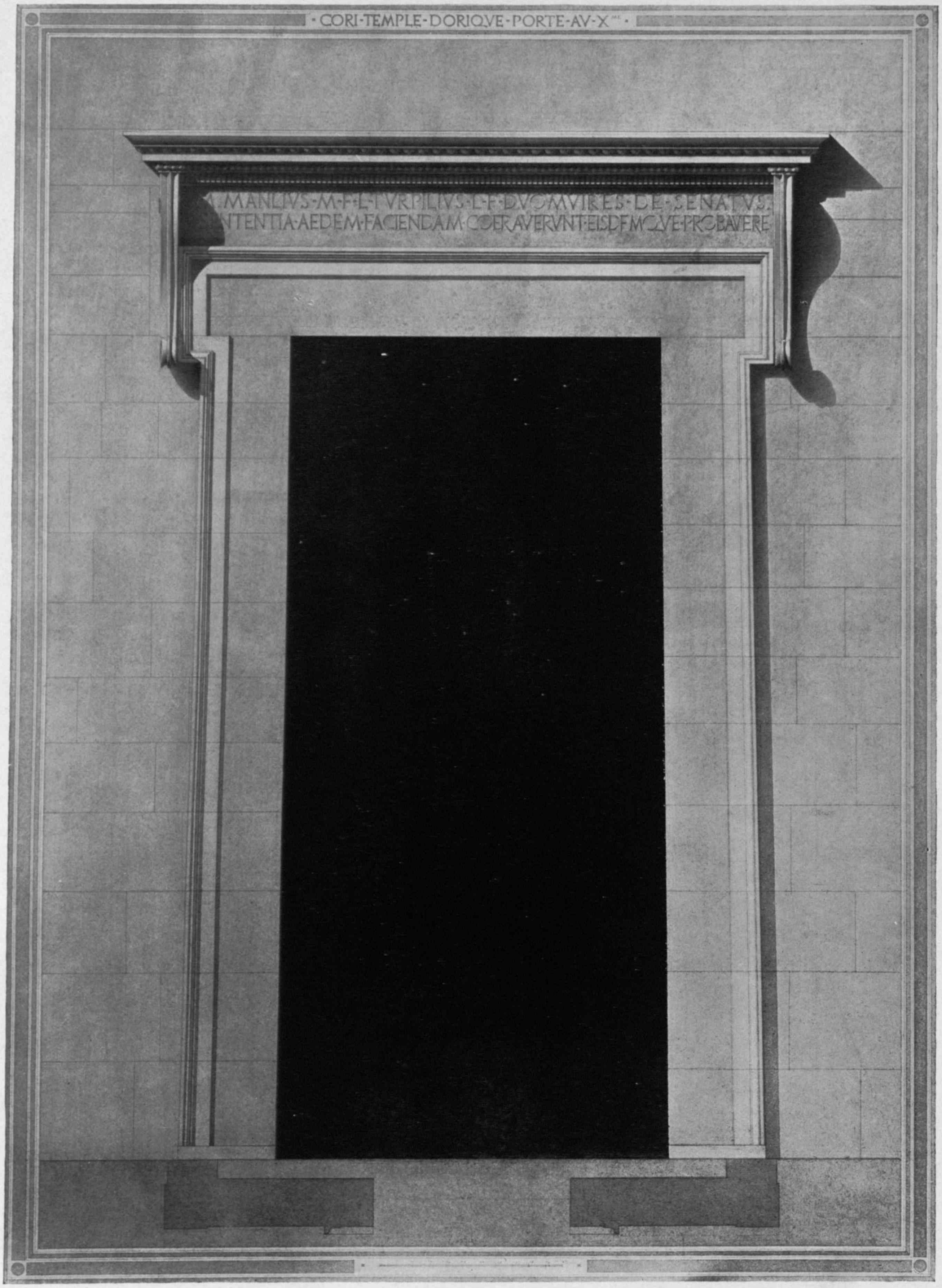

DORIC DOORWAY, BY EMMANUEL BRUNE

The original of this plate is in the
Gallery of the Department of Architecture

The Technology Architectural Record

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The proceeds of this publication are devoted to a Scholarship Fund, founded by the Architectural Society for students of the Department of Architecture of the Institute.

THE RECORD begins its third volume with this number. The reception of the publication has given us assurance that the paper is accomplishing the purpose for which it was started, and decides us also to return to four issues per volume, to appear respectively in December, March, June, and September. The new volume will be enlarged, and the new subjects to be introduced we are sure will still further increase in usefulness and interest.

In this issue two new features appear: the first, a department devoted to placing before the architectural profession the results of tests and experiments in the Institute laboratories which have to do with the advancement of modern methods of construction. Much work of this nature and of value to the architect has heretofore been published in scientific journals only. The second new feature is that of publishing illustrations of work of former students of the Department, accompanied when possible by an account of the conditions imposed upon the architect. We shall hope to show all types of buildings, landscape architecture, etc., which illustrate particularly modern methods of construction and requirements, and designed with an intelligent and artistic appreciation of our American building-materials.

THE RECORD is published for the "student" in actual practice as well as for the student in school, and we believe our purpose as outlined above can be made profitable to both. Furthermore, this effort to illustrate actual buildings as well as the school problems should serve the school a good purpose in keeping it in contact, at still another point, with the actual practice of architecture.

We take the first opportunity there has come to us to record the death, on April 30, of Theodore Minot Clark, who was Professor of Architecture at the Institute from 1881 to 1888. Perhaps Mr. Clark will be longest remembered as editor of *The American Architect*, a position he held during twenty-seven years. Both as an instructor and a writer upon professional topics he took high rank, as he did also in the practical exercise of his profession. Exceedingly well informed, his books on professional subjects always commanded attention, and achieved a well-merited and lasting popularity. He leaves a good name and a record of fine service done.

The school year 1909–1910 of the Department of Architecture opened with a much larger number of students than that of last year, and a full graduate class. The universities and colleges continue to send us a large quota. There were newly registered this year graduates from Brown, Dartmouth, and Harvard Universities, and from the Universities of Illinois, Nebraska, Oregon, and St. Louis, one from the Mississippi Agricultural and Mechanical College, one from Radcliffe, and one from the Rhode Island School of Design. Other students came prepared for advanced work at Technology from the Universities of Rochester and Washington, and from Amherst and Oregon Agricultural Colleges, also the Worcester Polytechnic Institute.

The curriculum has been readjusted so as to permit moving a large part of the more technical work from the third to the second year, in order to give fuller opportunities in the last two years for the artistic and historic studies. The first and second year men are now working according to this new schedule, and next year all the classes will be in line. This change is mainly to accentuate the fact that architecture is a fine art, and calls for an equipment of artistic and historic subjects in even a larger measure than those purely scientific; that the man unless he is an artist cannot be made an architect even by the most thorough engineering training. However, this by no means belittles the fact that architecture is based on sound construction, and that the architect must be scientifically trained to deal intelligently with all structural questions. It must be remembered that whether the architect is prepared to accomplish everything himself or must be aided by other agencies, the fact remains that he is responsible for his building as a whole, not only for its decorative side but its construction, its planning, and its final equipment with complicated systems of mechanical, electrical, and sanitary apparatus.

There is probably to-day no form of modern construction that is interesting investigators and engineers more than that of armored concrete. Perhaps in no form of construction is the exact distribution of the internal stresses so little known. Various methods of design for the beam of concrete and steel have been proposed. These methods differ very materially one from another in some of their fundamental assumptions. No one of those yet proposed is ideal; some are undoubtedly far from correct. A paper by Professor Gaetano Lanza and Mr. Lawrence Smith, read by Professor Lanza before the American Society of Mechanical Engineers, and reprinted on another page of THE RECORD, is of exceeding interest. In it comparison has been made between results as given by three of the best known methods of beam design and results as given by actual experiment on reinforced beams in the testing-machine. The method of design which gives results most nearly like those found to exist in the actual specimens tested is that of Considère. His method differs from the others discussed in that it assumes some of the concrete below the neutral axis of the beam to carry tension. Professor Lanza has been very conservative in his conclusions drawn from these tests, and while he in no way commits himself to the special theory of Considère, his results seem to indicate clearly that an ideal method of design should assume the concrete to carry some tension.

(*Continued on pages 23 and 27*)

Architectural Engineering

Stresses in Reinforced-Concrete Beams

Comparison of Experimental Results with Results Obtained from the Use of Three Theories of Distribution of Stresses

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Reprinted from the Journal of The American Society of Mechanical Engineers

MANY experiments have been performed on the breaking-strength of reinforced-concrete beams, and in the course of them many observations have been made to determine quantitatively some of the phenomena attendant upon the application of the breaking-load, and also upon that of smaller loads. Nevertheless, it is well known that the observations made thus far are not sufficient to furnish the means for determining the actual distribution of the stresses, and hence for the deduction of reliable formulæ for the computation of the direct stresses, shearing stresses, diagonal stresses, deflections, position of the neutral axis, etc., under a given load.

2. The test of the validity of such formulæ should be their agreement with the results of experiments when the loads employed are about one-fourth or one-third the ultimate loads; because, when the loads are greater, the ratio of stress to strain varies very considerably for the different fibres, while for loads smaller than one-fourth of the ultimate, unknown initial stresses are liable to exert so great an influence as to interfere with the deductions.

3. The object of this paper is to make a comparison of (*a*) the position of the neutral axis, (*b*) the stress in the steel, (*c*) the stresses in the concrete, and (*d*) the deflection, as determined by experiment, with the same quantities as computed by three well-known theories of the distribution of the stresses. The comparison was made in the cases of eleven beams, in the testing of which the necessary observations were taken. Of the eleven, five were tested in the Laboratory of Applied Mechanics of the Massachusetts Institute of Technology, and six in the laboratory of the University of Illinois.

4. The reinforcement consisted in each case of one or more longitudinal bars placed near the bottom of the beam, and equal loads were applied at the two points which divided the span into thirds.

5. The three theories employed in making the calculations, all of which assume that at any given section the strain in any fibre is proportional to the distance of the fibre from the neutral axis, will be denoted by *A*, *B*, and *C* respectively, and may be described as follows, the notation used in lettering the figures being explained subsequently:

A This theory, which is very extensively employed, makes the assumption that at any given section none of the concrete below the neutral axis can be relied upon to resist tension; and, further, that the stress is proportional to the strain, not only in the steel, but also in the concrete.

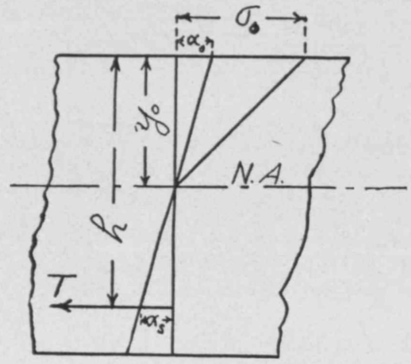


FIG. 1. THEORY A: DISTRIBUTION OF STRAINS AND STRESSES AT A CROSS-SECTION

6. This method is used by those who employ it to determine (*a*) the position of the neutral axis, (*b*) the stress in the steel, (*c*) the stress in the concrete, and sometimes the shearing stress at the neutral axis; but practically no attempt is made to compute the deflections by it. Nevertheless, for the purpose of comparison, deflection formulæ deduced on this basis will be given. The distribution of the strains and stresses at a cross-section is shown in Fig. 1.

B This theory, which was proposed by Prof. A. N. Talbot, also makes the assumption that at any given section none of the concrete below the neutral axis can be relied upon to resist tension; but instead of assuming the proportionality of stress to strain in the concrete, the assumption is made that the stress at any fibre can be represented graphically by the corresponding abscissa of a parabola drawn through the neutral axis; the axis of the parabola being at right angles to the section, and its vertex at the end of the abscissa, which would represent the crushing-strength per square inch of the concrete were the plot continued to such a height as to correspond to this crushing-strength.

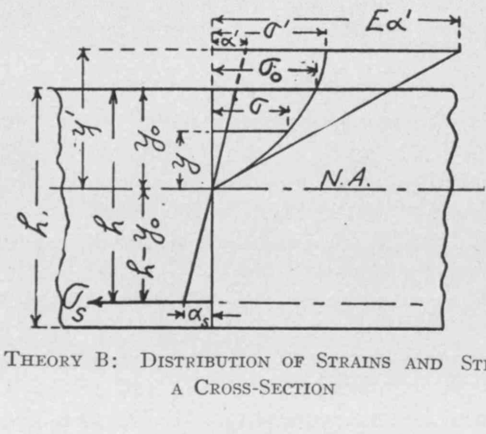


FIG. 2. THEORY B: DISTRIBUTION OF STRAINS AND STRESSES AT A CROSS-SECTION

7. The quantities calculated by this theory are the same as in case *A*, and again deflection formulæ will be deduced on this basis for the same reason as there stated. The distribution of the strains and stresses at a cross-section is shown in Fig. 2.

C The third theory is that proposed by Mr. Considère. He claims that whereas in a plain concrete beam the concrete on the tension side cracks when the extension has reached 0.01 to 0.02 per cent, in a reinforced-concrete beam the concrete on the tension side can undergo many times this extension without cracking.

8. Among the tests which he cites in confirmation of this view is the following. He says that he subjected one reinforced-concrete beam to a load that produced in the lower fibre of the concrete an elongation of 0.063 per cent as determined by measurement, and another such beam to a load that produced in the lower fibre of the concrete an elongation of 0.13 per cent; that he then removed the loads, chipped off the concrete below the reinforcement, and removed the reinforcing bars, after which he smoothed off the lower surface of the remaining portion of the beam and sawed out a concrete plank from the lower side. He says that not only did this plank not fall to pieces, but that on loading it transversely it bore as much as would be expected from a plain concrete plank of the same dimensions.

9. In view of the above, Mr. Considère suggests that the distribution of the stress at a section is as shown in Fig. 3, the compressive strength being represented by the triangle *OABO*, and the tensile strength in the concrete by the trapezoid *OCEFO*, the value of *CD* being equal to the yield point of the concrete in tension; and that for greater elongations the tensile stress does not increase.

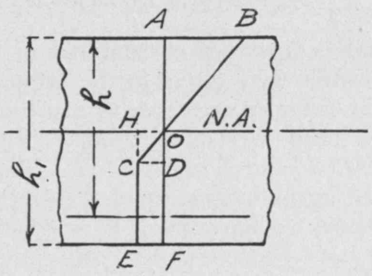


FIG. 3. DISTRIBUTION OF STRAINS AND STRESSES ACCORDING TO CONSIDÈRE'S THEORY

10. However, inasmuch as the assumption of this distribution would lead to great complexity in the calculations, he proposes as a sufficiently close approximation that for the trapezoid *OCEFO* in Fig. 3 we substitute the rectangle *OHEFO*. In this paper this approximation will be made in obtaining the formulæ on the basis of *C*.

11. Before obtaining the formulæ needed for making the calculations, the notation used throughout will be explained.

Let a_o = strain in concrete at upper fibre of beam.
a_s = strain in steel reinforcement.
E = ratio of stress to strain in concrete. In *B* this will denote the initial ratio of stress to strain.
E_s = ratio of stress to strain in steel.
$r = \frac{E_s}{E}$
σ_o = compressive outside fibre stress per square inch in concrete.
σ_s = stress per square inch in steel.
a_s = area of section of steel reinforcement in square inches.
$T = \sigma_s\, a_s$.
b = breadth of beam.
$n = \frac{ra_s}{b}$
h = distance from top of beam to centre of reinforcement, inches.
h_1 = total depth of beam, inches.
y_o = distance from top of beam to neutral axis.
ρ = radius of curvature of vertical longitudinal section of neutral layer.
W = total load applied.
M = greatest bending-moment under this load.
l = span, inches.
v = deflection at distance x from left-hand support.
v_o = greatest deflection; i.e., deflection at middle.

The above is the notation needed for *A*.

12. In *B* the same notation is used, with the following in addition:

Let y = distance of any fibre above the neutral axis.
y^1 = distance above neutral axis at which the fibre would be subjected to the crushing-strength.
a = strain of fibre at distance y above neutral axis.
a^1 = ultimate compressive strain of concrete.
σ = stress in fibre at distance y above neutral axis.
σ^1 = ultimate compressive strength of concrete.
$q = \frac{a_o}{a^1}$
$n_1 = \frac{3\,r\,a_s}{b\,(3-q)}$
d_1 = distance above neutral axis to point of application of resultant of compression.
d_2 = distance below top of beam to point of application of resultant of compression.

13. In *C* the same notation is used, with the following in addition:

Let t = yield-point of concrete in tension.
$d = h_1 - h$.

FORMULÆ

14. Taking up the three theories successively, the formulæ needed to make the computation of the values of y_o, σ_s, σ_o, and v_o will now be given, the deduction being left to the reader. By Method A:

A

$$y_o = \sqrt{n^2 + 2\,n\,h} - n \quad \text{(1)}$$

$$\sigma_s = \frac{3\,M}{(3\,h - y_o)\,a_s} \quad \text{(2)}$$

$$\sigma_o = \frac{6\,M}{(3\,h - y_o)\,by_o} \quad \text{(3)}$$

$$v_o = -\frac{23\,Wl^3}{1296\,A} \quad \text{(4)}$$

where

$$A = E\left\{ ra_s\,(h - y_o)^2 + \frac{b\,y_o^3}{3} \right\}$$

B

15. In order to find y_o, σ_s, and σ_o by Method *B*, we have the following equations, all of which include *q:*

$$y_o = \sqrt{n_1^2 + 2\, n_1\, h} - n_1 \quad \ldots\ldots\ldots\ldots (5)$$

$$\sigma_s = \frac{M}{a_s \left\{ h - y_o \dfrac{4-q}{4\,(3-q)} \right\}} \quad \ldots\ldots\ldots\ldots (6)$$

$$\sigma_o = \frac{M}{b\, y_o \left\{ \dfrac{3-q}{3\,(2-q)}\, h - \dfrac{4-q}{12\,(2-q)}\, y_o \right\}} \quad \ldots\ldots (7)$$

Hence before we can find the values of y_o, σ_s, and σ_o we need to determine *q*, and this will have to be done approximately. For this purpose we can use the equation:

$$q^2 - 2q = -\frac{\sigma_o}{\sigma^1} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

16. Plot a curve having $\frac{\sigma_o}{\sigma^1}$'s for abscissæ, and *q*'s for ordinates; then, using for σ_o a first approximation to its value, determine a first approximation for *q*. Then determine a second approximation for σ_o and from it a second approximation for *q*, etc.

17. In the calculations made here, with the load approximately one-third of the breaking-load, the value that has been employed is $q = 0.2$.

18. For the deflection we have

$$v_o = -\frac{23\, Wl^3}{1296\, A} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

where

$$A = E \left\{ r\, a_s\, (h - y_o)^2 + b\, y_o^3 \frac{8 - 3q}{24} \right\}$$

C

19. In order to obtain y_o by Method *C* we need to solve the equation of the fourth degree in y_o:

$$b\, y_o^4 + 2\, \{b\, (h + d) + 3\, r\, a_s\}\, y_o^3 - 3\, \Big\{b\, (h + d)^2 + 6\, r\, a_s\, h - 2\frac{M}{t}\Big\}\, y_o^2 + 6\, r\, a_s \left\{\frac{2\,M}{t\,b} + 3\,h^2 - d^2\right\} y_o - 6\, r\, a_s\, h \left\{\frac{2\,M}{t\,b} + h^2 - d^2\right\} = 0 \quad \ldots\ldots (10)$$

20. The solution can readily be effected graphically for any numerical case by writing *u* equal to the entire left-hand side of the equation, and plotting the resulting curve with y_o's as abscissæ and *u*'s as ordinates; then the value of y_o where this curve crosses the axis of abscissæ will be the value of y_o desired. Of course the equation has four roots, but the one required can be easily identified, as it must give a neutral axis that lies within the section.

21. In solving this equation, some value of *t*, the tensile yield-point of the concrete, must be used. Considère suggests 170 pounds per square inch for the concrete used by him, which was about six months old and of a composition of nearly 1 — 2.5 — 2.5.

22. In the calculations made in this paper, $t = 100$ pounds per square inch has been used, as the concrete was from thirty to sixty days old and its composition was 1—3—6. After y_o has been found we can find σ_s and σ_o from the following equations respectively:

$$\sigma_s\, a_s \frac{3\,h - y_o}{3} = M - t\, b\, (h_1 - y)\, \frac{3\,h_1 + y_o}{6} \quad \ldots (11)$$

$$\sigma_o \frac{b\, y_o}{2} \frac{3\,h - y_o}{3} = M + t\, b\, (h_1 - y_o)\, \frac{2\,h - h_1 - y_o}{2} \quad \ldots (12)$$

or more easily from the formulæ:

$$\sigma_o = \frac{t\, b\, (h_1 - y_o)}{\dfrac{b\, y_o}{2} - r\, a_s \dfrac{h - y_o}{y_o}} \quad \ldots\ldots\ldots\ldots\ldots (13)$$

$$\sigma_s = r\, \sigma_o \frac{h - y_o}{y_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

For the deflection we have

$$v_o = -\frac{23\, Wl^3}{1296\, A} \quad \ldots\ldots\ldots\ldots (15)$$

where

$$A = E \left\{ \frac{r\, a_s\, (h - y_o)\, (2\,h - h_1 - y_o)}{2} + \frac{b\, y_o^2\, (3\,h_1 + y_o)}{12} \right\}$$

COMPARISON OF THE VALUES OF y_o, σ_s, σ_o, AND v_o AS COMPUTED BY THE VARIOUS THEORIES WITH THOSE DETERMINED BY EXPERIMENT.

23. This comparison is exhibited in the tables. The first five beams were tested in the Laboratory of Applied Mechanics of the Massachusetts Institute of Technology, and for these we have used $E_s = 28{,}000{,}000$ and $E = 2{,}335{,}000$, and hence $r = 12$. The last six beams were tested in the laboratory of the University of Illinois, and for these we have used $E_s = 30{,}000{,}000$, and $E = 2{,}000{,}000$, and hence $r = 15$. All eleven were made of 1—3—6 concrete, the ages being given in the tables. All were loaded with two equal loads applied at points dividing the span into thirds.

TABLE 1. DETAILS OF REINFORCED-CONCRETE BEAMS

ALL BEAMS LOADED AT THIRD POINTS

Designation of Beam	Age Days	*b* Inches	*h* Inches	h_1 Inches	Span Feet	Rods: Number	Rods: Size Inches Round	Steel a_s Area in Square Inches	p*
Massachusetts Institute of Technology									
A—1	53	8	10	12	11	1	1†	1.00	1.25
A—2	49	8	10	12	11	1	1‡	1.00	1.25
B—3	43	8	10	12	11	2	¾†	1.125	1.41
C—5	35	8	10	12	11	4	½†	1.00	1.25
E—9	54	8	10	12	11	2	⅞‡	1.53	1.91
University of Illinois									
11	65	8	10	11	12	4	½	0.785	0.99
27–'04	63	12	12	13½	14	4	¾†	2.25	1.56
28	60	8	10	11	12	4	¾	1.77	2.22
33	60	8	10	11	12	3	¾	1.325	1.66
35	60	8	10	11	12	{3 2	½ ¾}	1.473	1.84
45	61	8	10	11	12	{3 2	½ ¾}	1.473	1.84

* Reinforcement of area above centre line of steel, per cent.
† Square.
‡ Twisted.

TABLE 2. DATA FROM TESTS ON REINFORCED-CONCRETE BEAMS

All Beams Loaded at Third Points

Designation of Beam	Breaking-Load*	Nearest ⅓ Load†	Inches Actual (Plot)			Deflection	
			y_0	σ_0	σ_s	Load Considered W	v_0 (Plot)
Massachusetts Institute of Technology							
A—1	15250	5250	5.4	726	7941	4000	0.0731
A—2	16500	5250	5.3	650	7644	4000	0.0749
B—3	15950	5250	5.5	565	6615	4000	0.0660
C—5	16240	4600	4.6	781	8246	4000	0.1015
E—9	22250	6250	5.1	776	7563	5000	0.0769
University of Illinois							
11	11000	4000	4.8	740	11700	4000	0.175
27–'04	26900	9000	6.8	680	8250	9000	0.162
28	14300	5000	5.8	760	7800	5000	0.141
33	14400	5000	4.9	580	9000	5000	0.137
35	15000	5000	6.0	660	6750	5000	0.100
45	12400	4000	6.0	660	6750	4000	0.150

* Exclusive of weight of beam.
† Used in plots and in calculation for y_0, σ_s, σ_0.

TABLE 3. RESULTS OBTAINED BY EXPERIMENT AND BY COMPUTATION

Massachusetts Institute of Technology Beams: $r = 12$, $E = 2{,}335{,}000$.
University of Illinois Beams: $r = 15$, $E = 2{,}000{,}000$.

Designation of Beam	y_0				σ_0			
	Actual or Plot	A	B $q = 0.20$	C $t = 100$	Actual or Plot	A	B $q = 0.20$	C $t = 100$
Massachusetts Institute of Technology								
A—1	5.4	4.18	4.29	4.94	726	801	760	759
A—2	5.3	4.18	4.29	4.94	650	801	760	759
B—3	5.5	4.36	4.47	5.10	565	774	734	640
C—5	4.6	4.18	4.29	5.06	781	703	666	653
E—9	5.1	4.86	4.97	5.45	776	844	802	810
University of Illinois								
11	4.8	4.15	4.27	4.93	740	670	634	645
27–'04	6.8	5.88	6.01	6.60	680	711	678	690
28	5.8	5.49	5.59	5.98	760	669	638	662
33	4.9	5.00	5.10	5.54	580	722	686	717
35	6.0	5.17	5.28	5.71	660	701	667	675
45	6.0	5.17	5.28	5.83	660	561	534	548

TABLE 4. RESULTS OBTAINED BY EXPERIMENT AND BY COMPUTATION

Massachusetts Institute of Technology Beams: $r = 12$, $E = 2{,}335{,}000$.
University of Illinois Beams: $r = 15$, $E = 2{,}000{,}000$.

Designation of Beam	σ_s				v_o			
	Actual or Plot	A	B $q = 0.20$	C $t = 100$	Actual or Plot	A	B $q = 0.20$	C $t = 100$
Massachusetts Institute of Technology								
A—1	7941	13420	13510	9333	0.0731	0.1163	0.1193	0.0921
A—2	7644	13420	13510	9333	0.0749	0.1163	0.1193	0.0921
B—3	6615	12000	12100	7374	0.0660	0.1076	0.1105	0.0865
C—5	8246	11755	11840	7650	0.1015	0.1163	0.1193	0.0887
E—9	7563	10720	10810	8110	0.0769	0.1105	0.1139	0.0942
University of Illinois								
11	11700	14190	14210	9950	0.175	0.1778	0.1824	0.1500
27–04	8250	11160	11240	8468	0.162	0.1822	0.1878	0.1573
28	7800	8296	8386	6672	0.141	0.1346	0.1400	0.1216
33	9000	10880	10960	8662	0.137	0.1592	0.1647	0.1406
35	6750	9842	9926	7609	0.100	0.1501	0.1549	0.1329
45	6750	7890	7941	5878	0.150	0.1201	0.1240	0.1033

TABLE 5. COMPARISON OF RESULTS

Per cent of Variation of Results on Tables 3 and 4 from the Actual Values Determined by Experiment

Designation of Beam	y_o			σ_s		
	A	B	C $t = 100$	A	B	C $t = 100$
Massachusetts Institute of Technology						
A—1	−22.59	−20.56	−8.52	69.00	70.13	17.54
A—2	−21.12	−19.05	−6.67	75.60	76.74	22.09
B—3	−20.73	−18.73	−7.27	81.41	82.92	11.47
C−5	− 9.13	− 6.74	10.00	42.55	43.53	−7.23
E−9	− 4.71	− 2 55	6.86	41.74	42.93	7.24
University of Illinois						
11	−13.54	−11 04	2.71	21.28	21.45	−14.96
27	−13.53	−11.61	−2.94	35.27	36.24	2.64
28	− 5.35	− 3.62	3.11	6.36	7.51	−14.45
33	2.04	4.09	13.06	20.83	21.78	− 3.76
35	−13.89	−12.00	−4.84	45.81	47.05	12.72
45	−13.84	−12.00	−2.84	16.89	17.65	−12.91
Average...	−12.40	−10.32	0.24	41.52	42.55	1.85

Values less than the actual are called negative.

TABLE 6

Per Cent of Variation of Results on Tables 3 and 4, from the Actual Values Determined by Experiment

Designation of Beam	σ_o			v_o		
	A	B	C $t = 100$	A	B	C $t = 100$
Massachusetts Institute of Technology						
A—1	10.33	4.68	4.55	59.09	63.20	25.99
A—2	23.23	16.92	16.77	55.27	59.23	22.96
B—3	36.99	29.91	13.27	63.03	67.44	31.07
C—5	− 9.98	−14.72	−16.39	14.58	17.54	−12.61
E—9	8.76	3.35	4.38	43.70	48.11	22.50
University of Illinois						
11	− 9.46	−14 34	−12.83	1.60	4.23	−14.29
27	4.56	− 0.29	1.47	12.47	15.92	− 2.90
28	−11.98	−16.05	−12.89	− 4.54	− 0.71	−13.76
33	18.28	18.28	23.62	16.20	20.22	2.63
35	6.21	1.06	2.27	56.01	54.90	32.90
45	−15.00	−19.10	−16.97	−19.93	−17.34	−31.15
Average...	6.19	0.88	0.66	26.50	30.25	5.76

Values less than the actual are called negative.

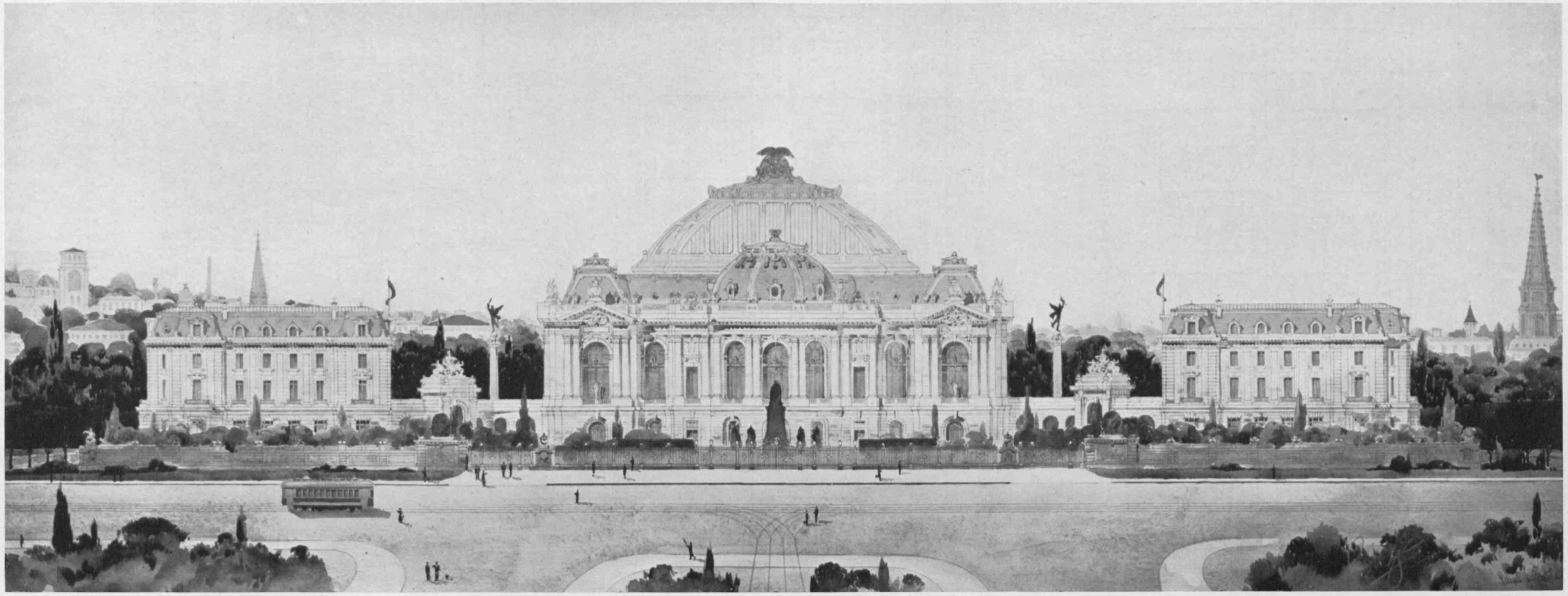
REMARKS AND CONCLUSIONS

24. The results seem to warrant the statement, in Paragraph 1, that "the observations made thus far are not sufficient to furnish the means for determining the actual distribution of the stresses, and hence for the deduction of reliable formulæ for the computation of the direct stresses, shearing stresses, diagonal stresses, deflections, position of the neutral axis, etc., under a given load." It follows, therefore, that whichever of the theories is adopted for practical use it can be regarded only as a sort of working hypothesis.

25. It seemed therefore desirable to compare the results of these three well-known theories with those obtained by experiment. This comparison can best be made by a detailed study of the tables, especially Table 5 and Table 6.

26. However, it seems plain, as far as the evidence of these eleven tests goes, that in deducing the values of y_o and σ_s theory *C* gives results much nearer those determined by experiment than either *A* or *B*, and the same

(Continued on page 23)

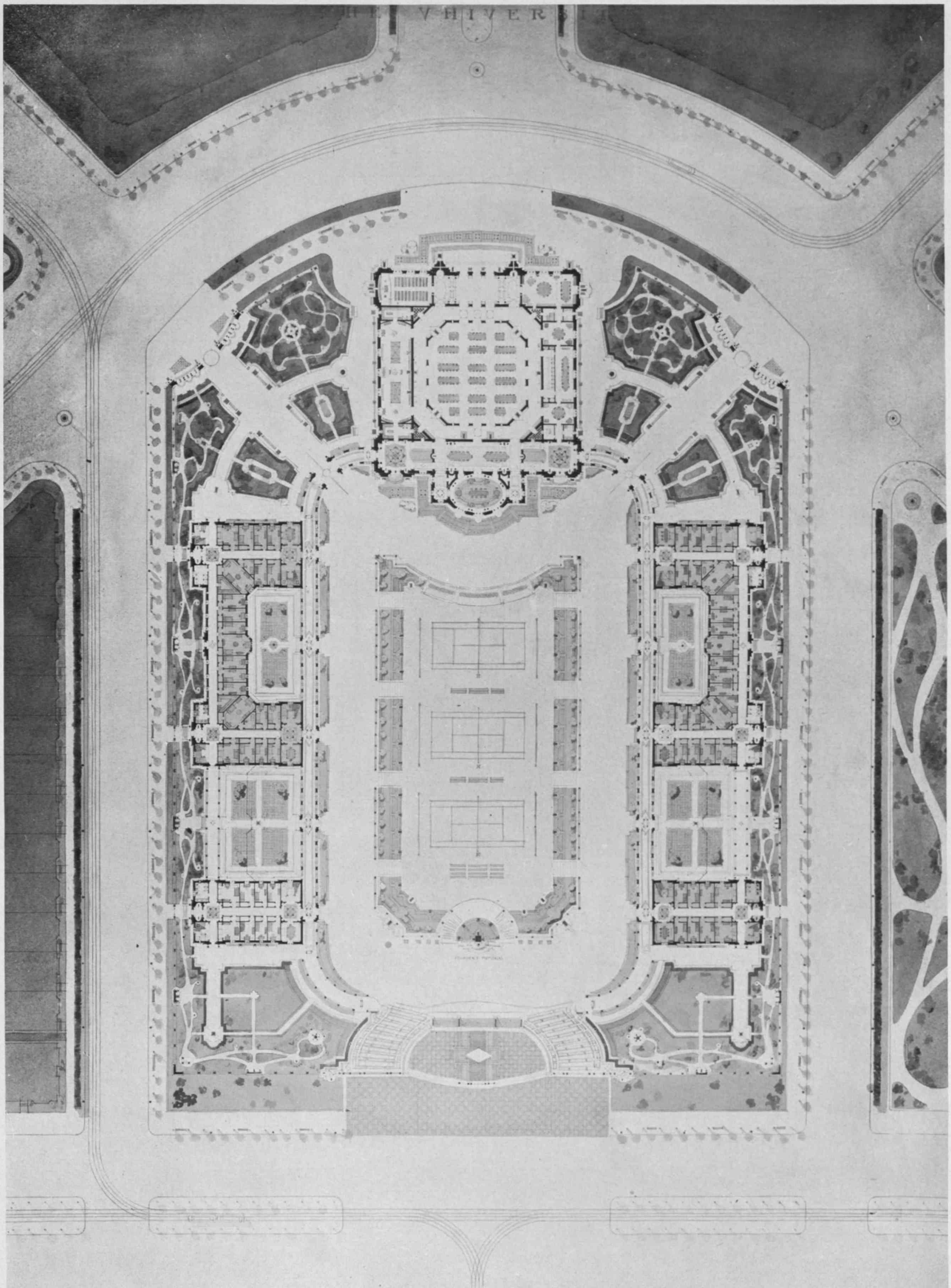


1909 Traveling Fellowship Competition

PRIZE DESIGN

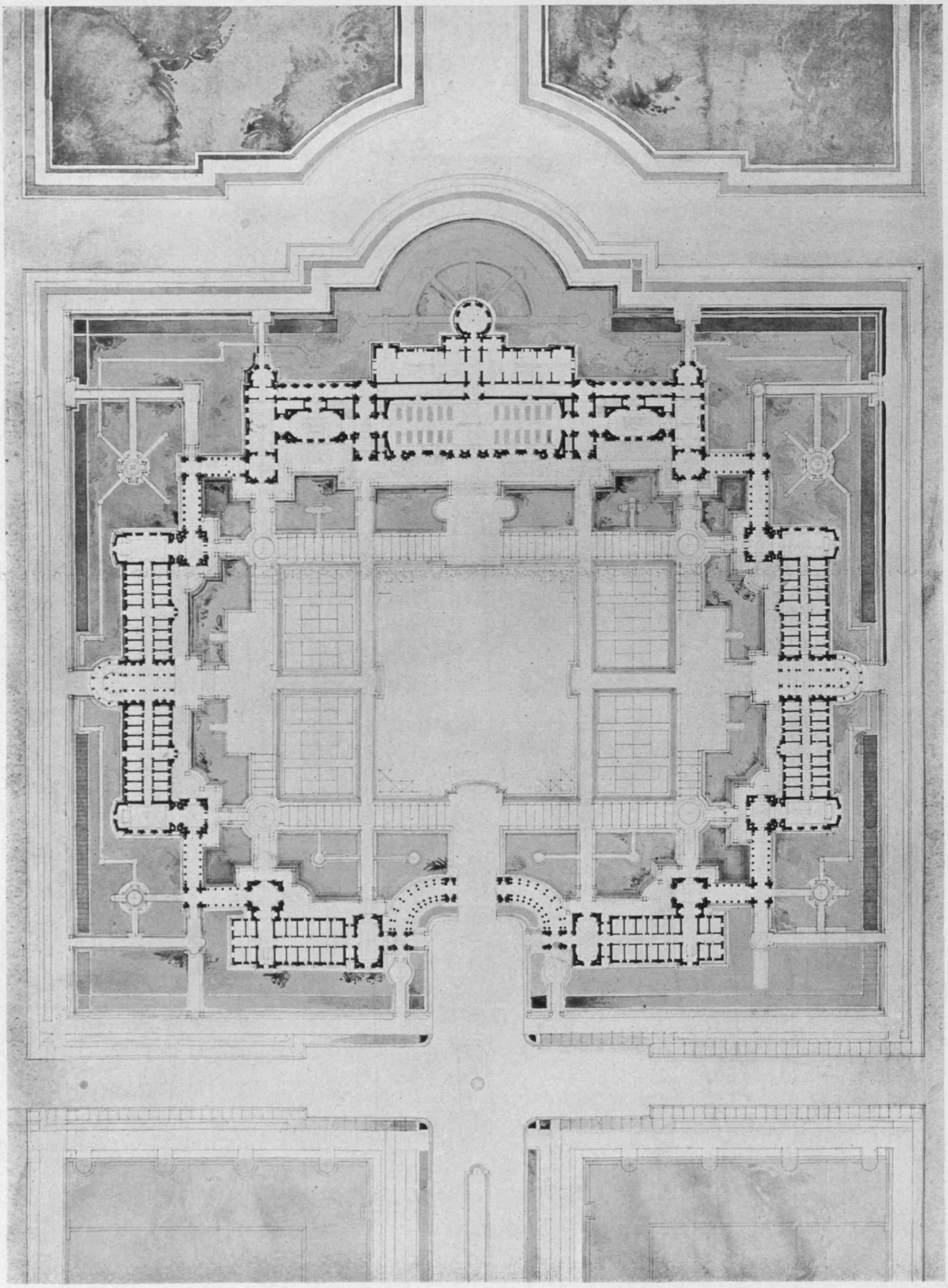
A TECHNOLOGY UNION, WITH DORMITORIES

RALPH J. BATCHELDER



A TECHNOLOGY UNION, WITH DORMITORIES

RALPH J. BATCHELDER

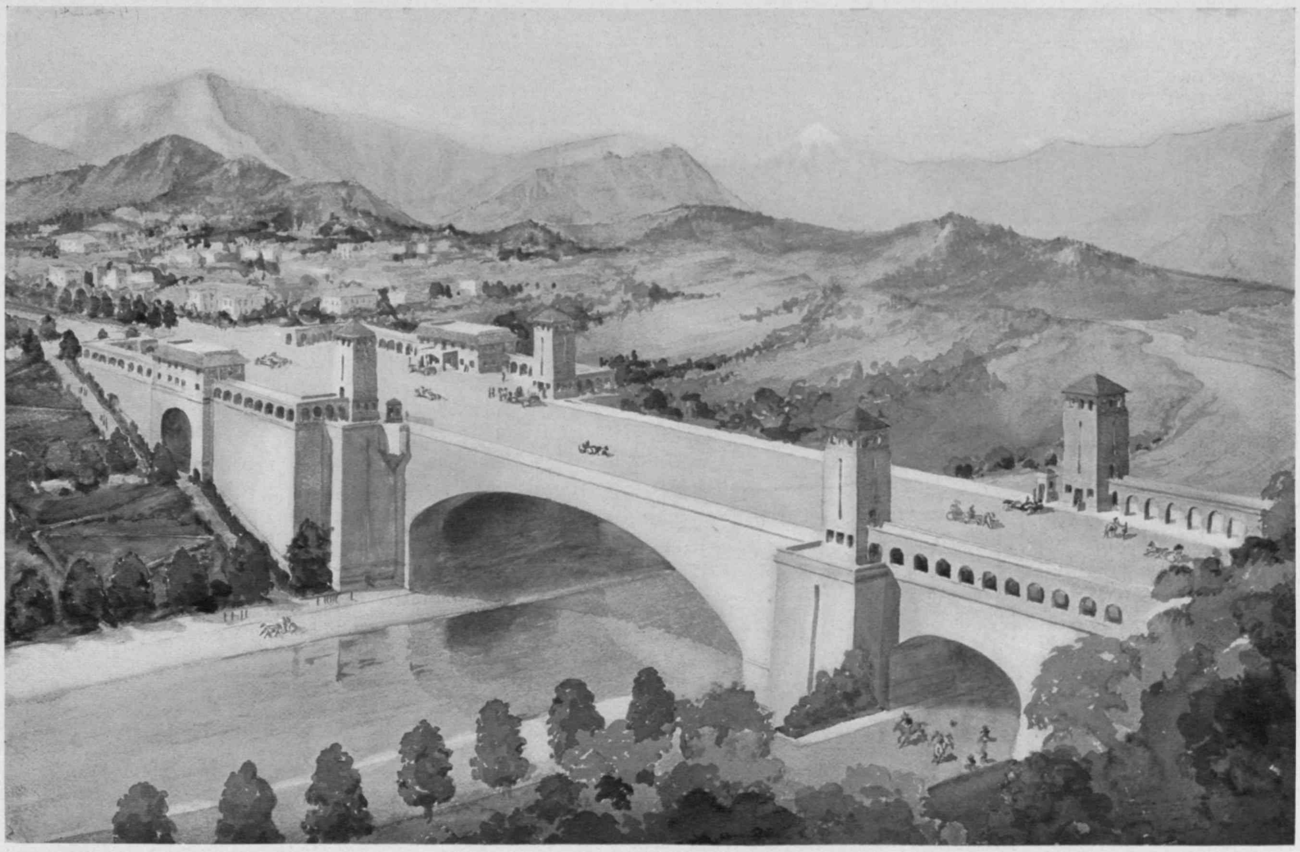


1909 Traveling Fellowship Competition

A TECHNOLOGY UNION, WITH DORMITORIES

H. D. CHANDLER

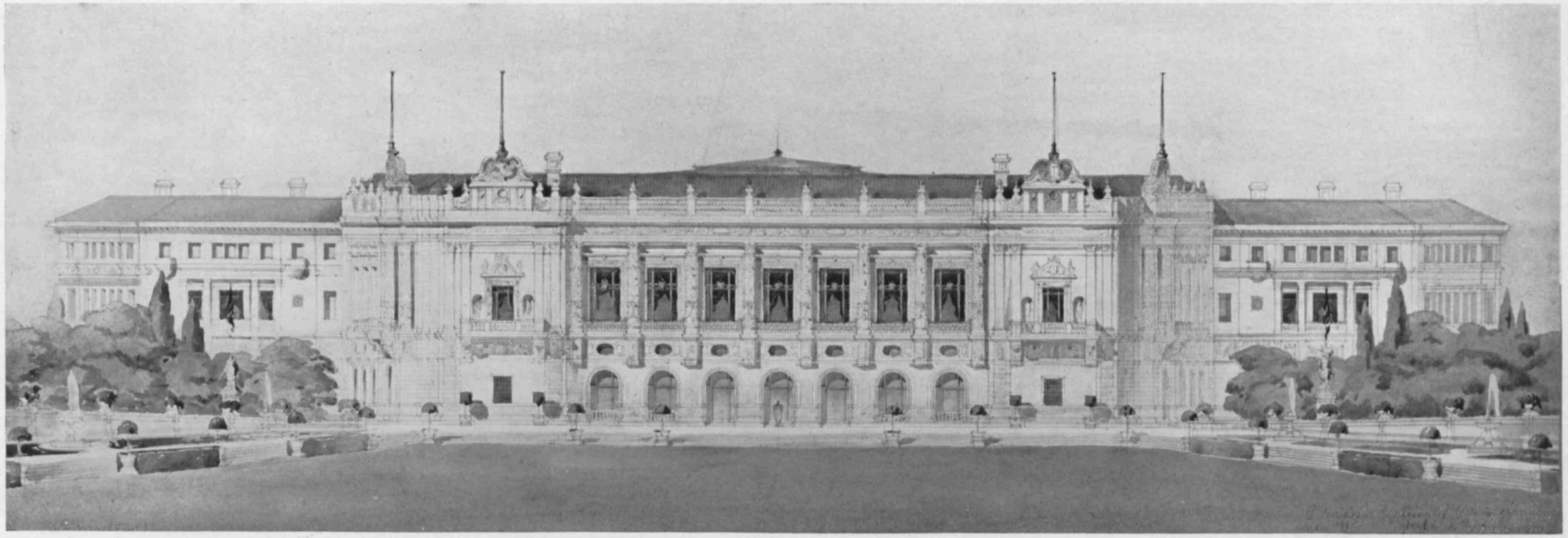
ADVANCED DESIGN, A FRONTIER BRIDGE BETWEEN THE UNITED STATES AND MEXICO



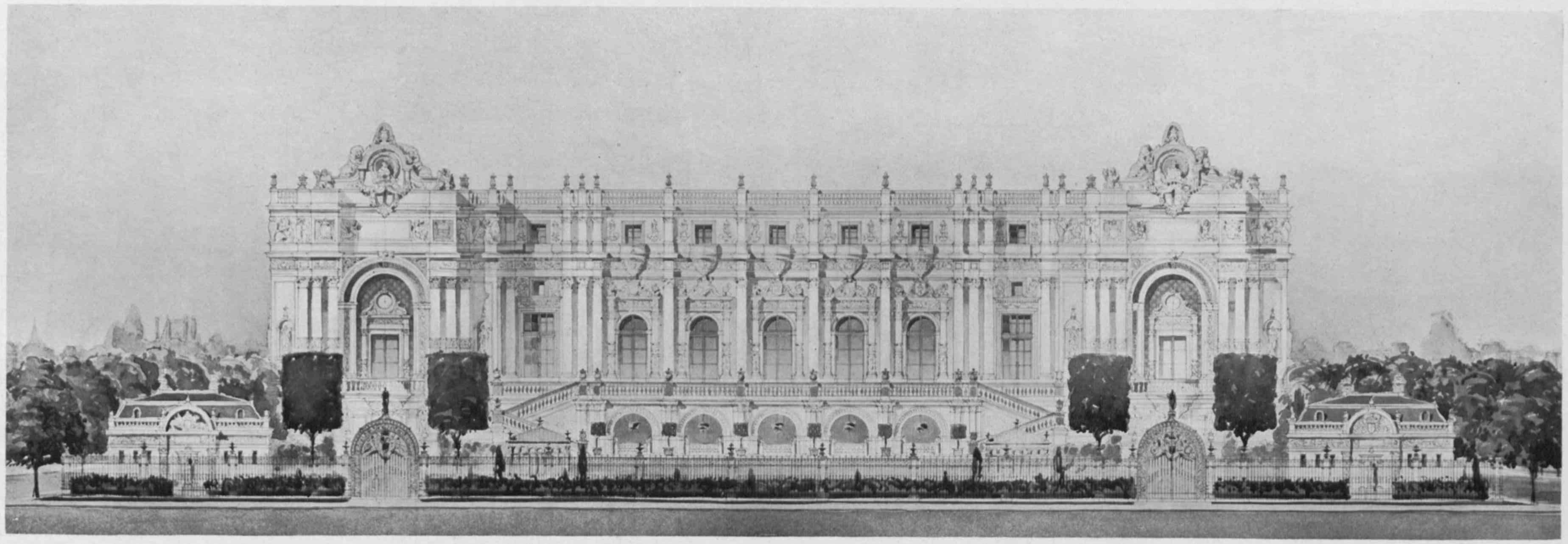
FIRST MENTION, R. KIBBEY

SECOND MENTION, C. C. FORD

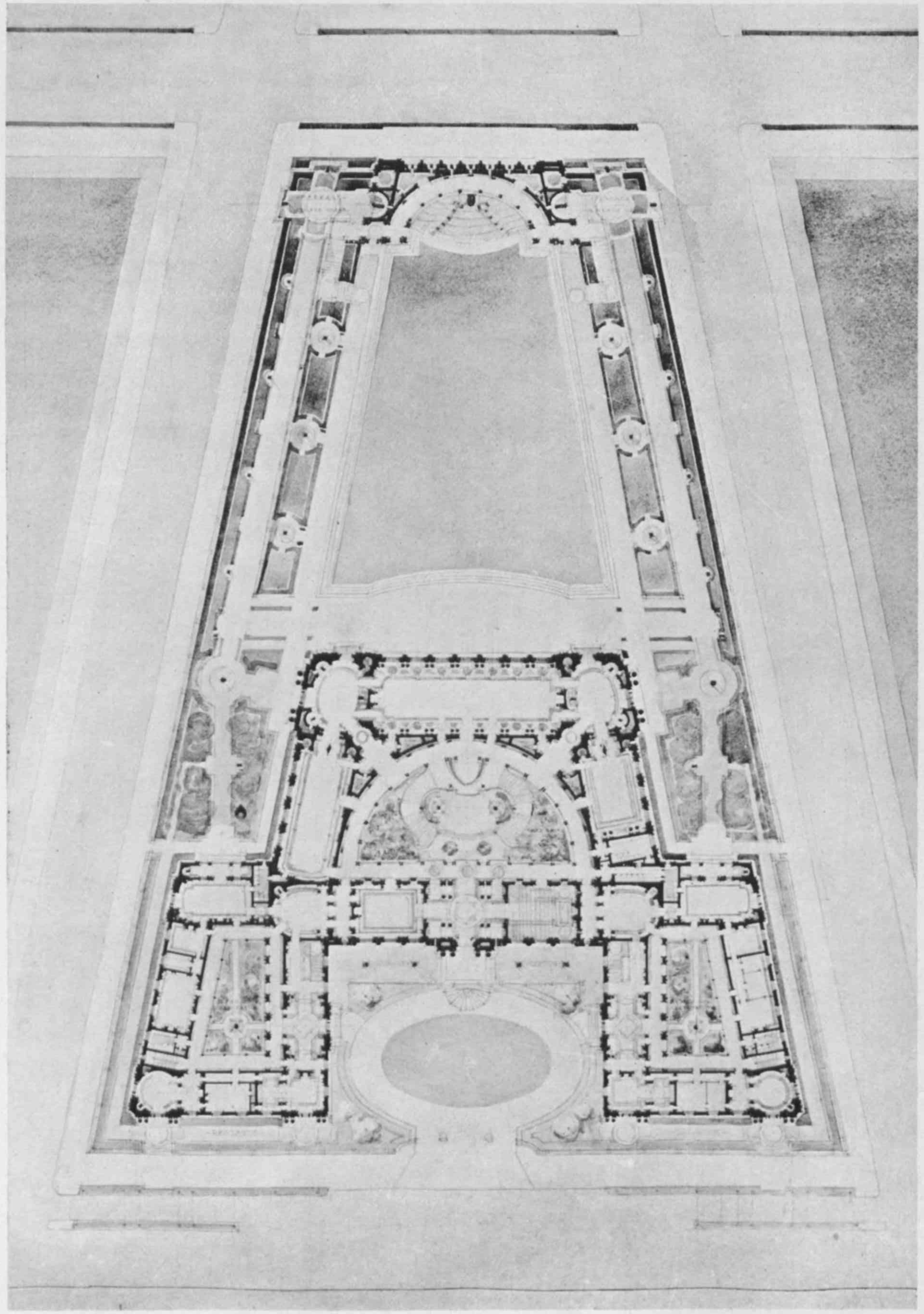
ADVANCED DESIGN, A MEXICAN EMBASSY AT WASHINGTON



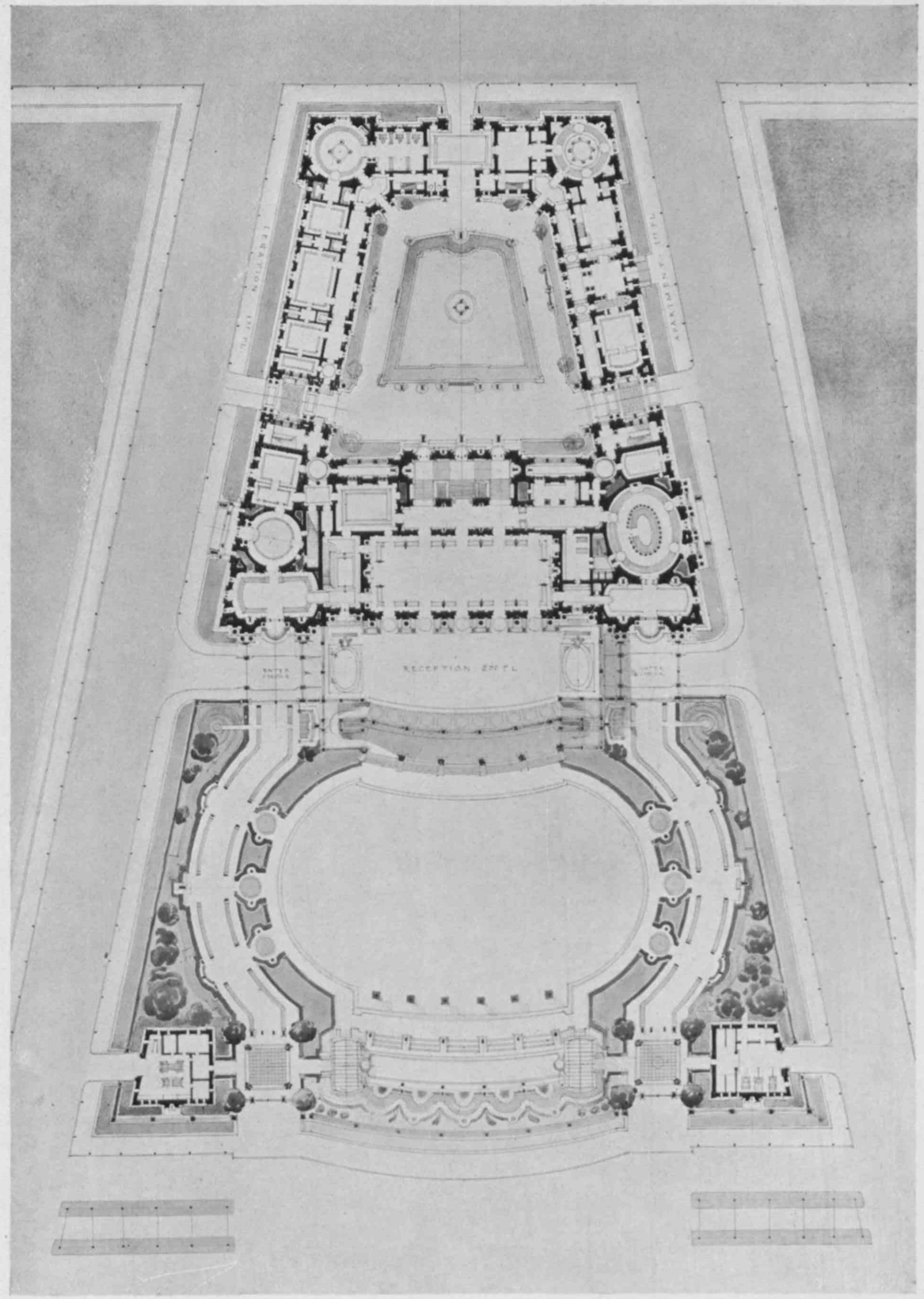
FIRST MENTION, J. T. MOHN



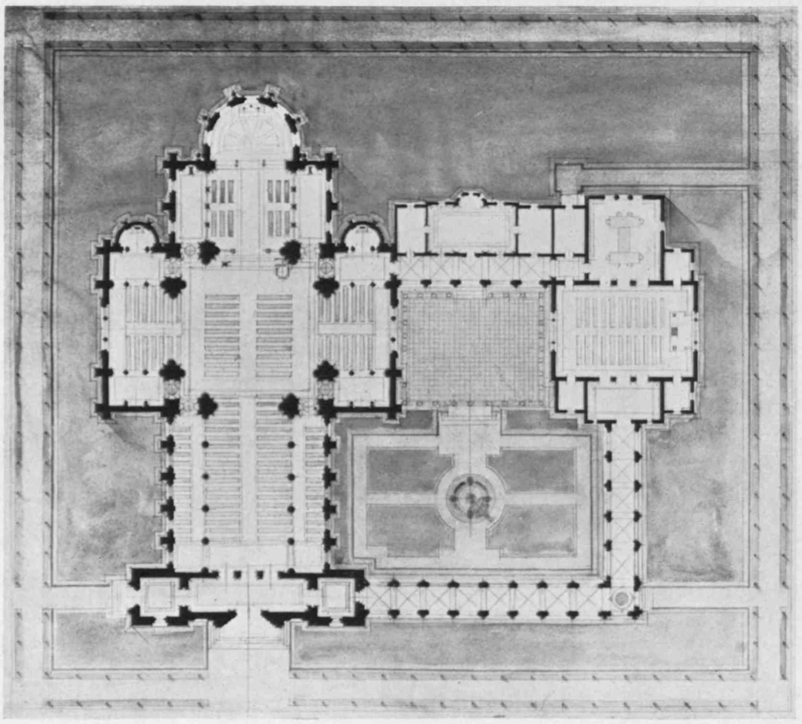
THIRD MENTION, E. I. WILLIAMS

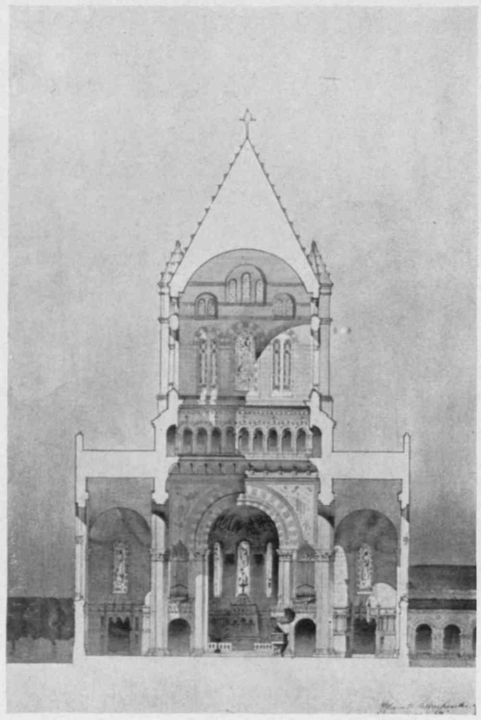


FIRST MENTION, J. T. MOHN



THIRD MENTION, E. I. WILLIAMS





THIRD YEAR OF DESIGN, AN EPISCOPAL CHURCH

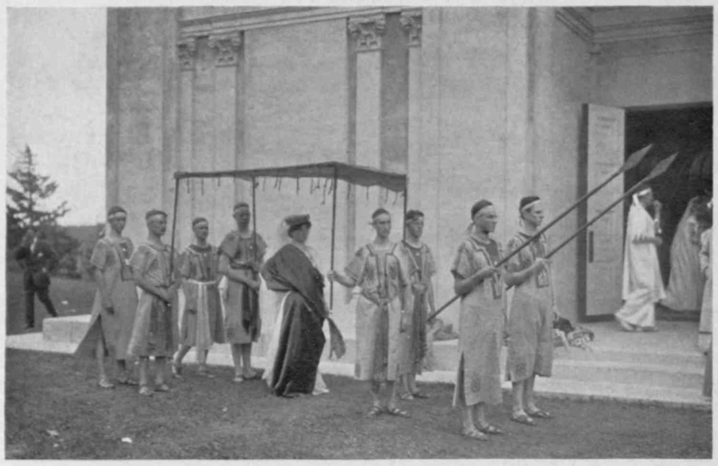
FIRST MENTION, K. E. CARPENTER

SAVINGS BANK OF BALTIMORE, BALTIMORE, MD. PARKER ('95), THOMAS ('95) & RICE ('91), ARCHITECTS

COMMONWEALTH TRUST BUILDING, BOSTON PARKER ('95), THOMAS ('95) & RICE ('91), ARCHITECTS

Pettingell-Andrews Co., Lighting Fixtures

The Building for Arts, at Bar Harbor, as its name implies, provides a place where good music can be heard, where dramatic entertainments can take place, where exhibitions like the annual flower show can be held; and it provides a hall, a stage, and outside to the left an open amphitheatre with one side of the building as a porticoed stage and with the pine-clad slope as an encircling foyer, while on the other side towards the valley is a terraced lawn for open-air pageants. It stands in the woods outside the town, against a background of evergreen hills. The program was simple: the landscape with its clear sky and ranging mountains, the quality of the festivals which were to be held there, the ideals of the founders, all seemed to impel the architect to impress the classic spirit on his design.



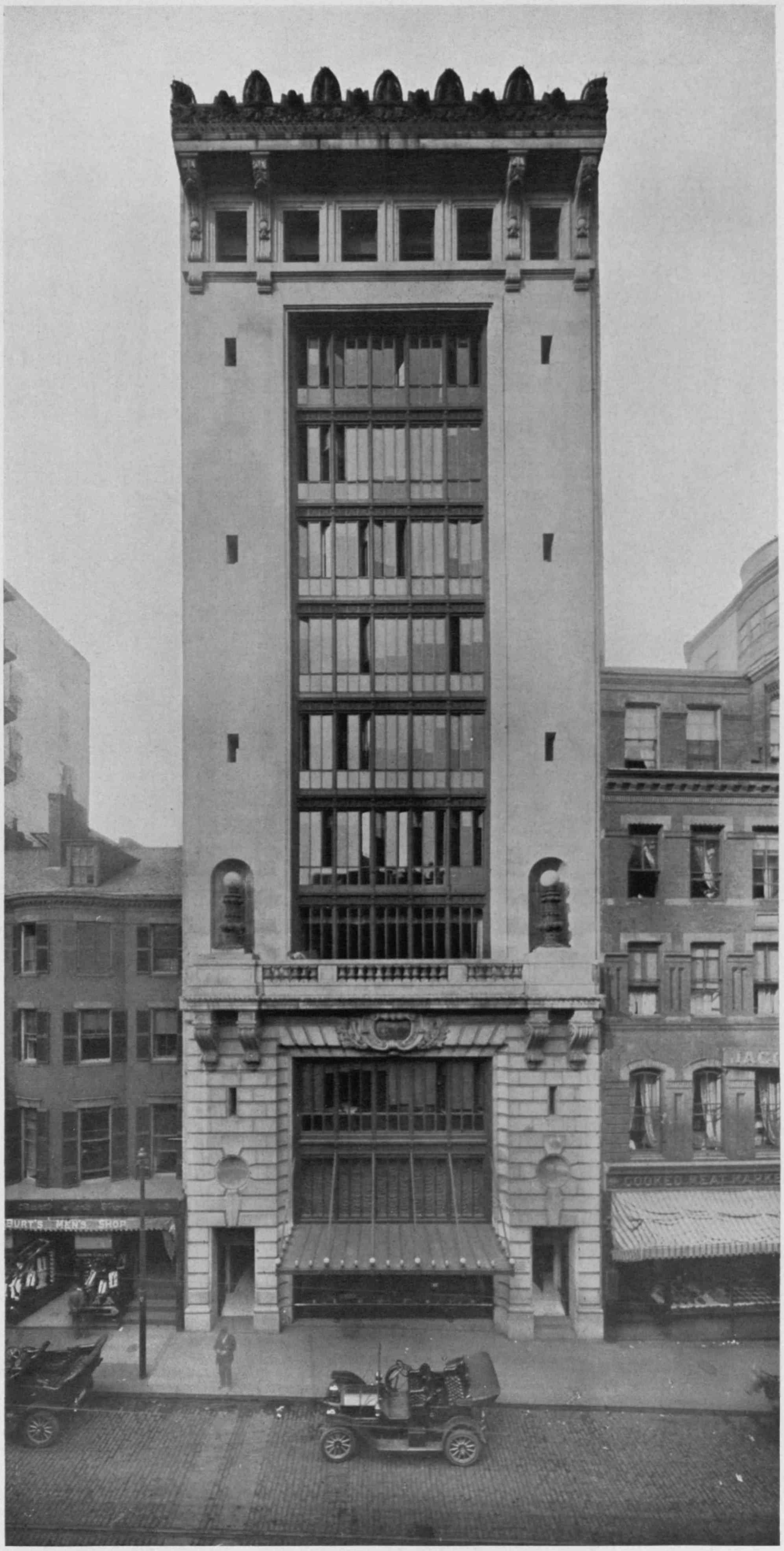
BUILDING FOR ARTS, BAR HARBOR, ME. Photos by T. E. Marr, Boston GUY LOWELL ('94), ARCHITECT

[OVER]

LAWRENCE HOSPITAL, BRONXVILLE, N. Y. WILDER & WHITE ('99), ARCHITECTS

The new Pi Eta Club House replaced a frame dwelling used as a club, with a theatre attached. The new building required the joining of the theatre with large clubrooms, etc.; in effect the work was an addition to the theatre. The available space was limited. The desire was to impart to the building a semi-domestic character, based on the New England tradition of Georgian architecture.

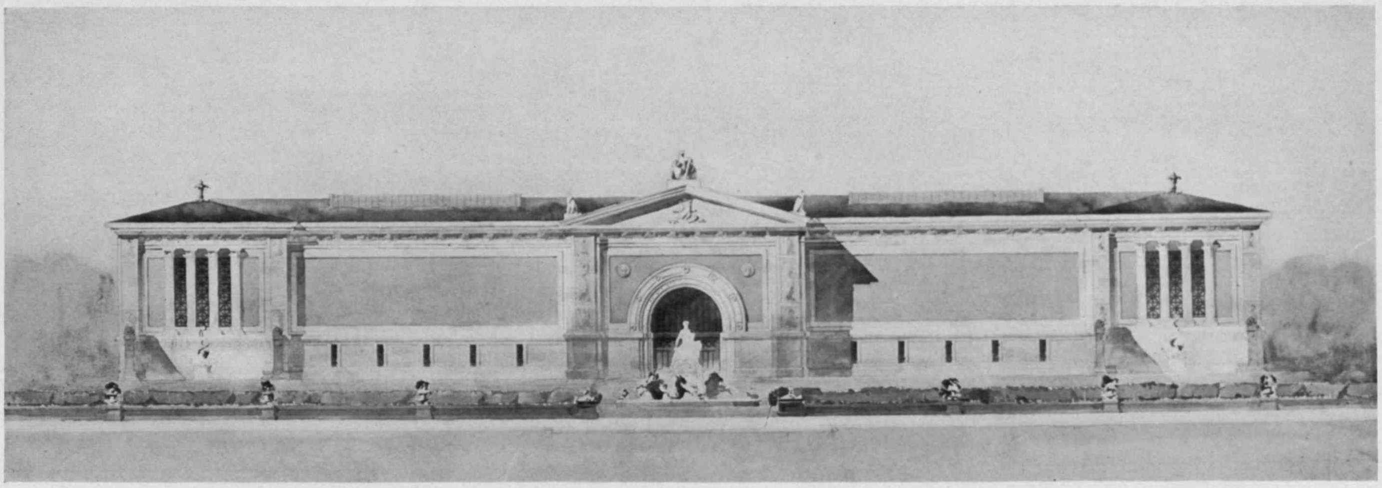
PI ETA CLUB HOUSE, CAMBRIDGE, MASS. PUTNAM ('98) & COX ('98), ARCHITECTS

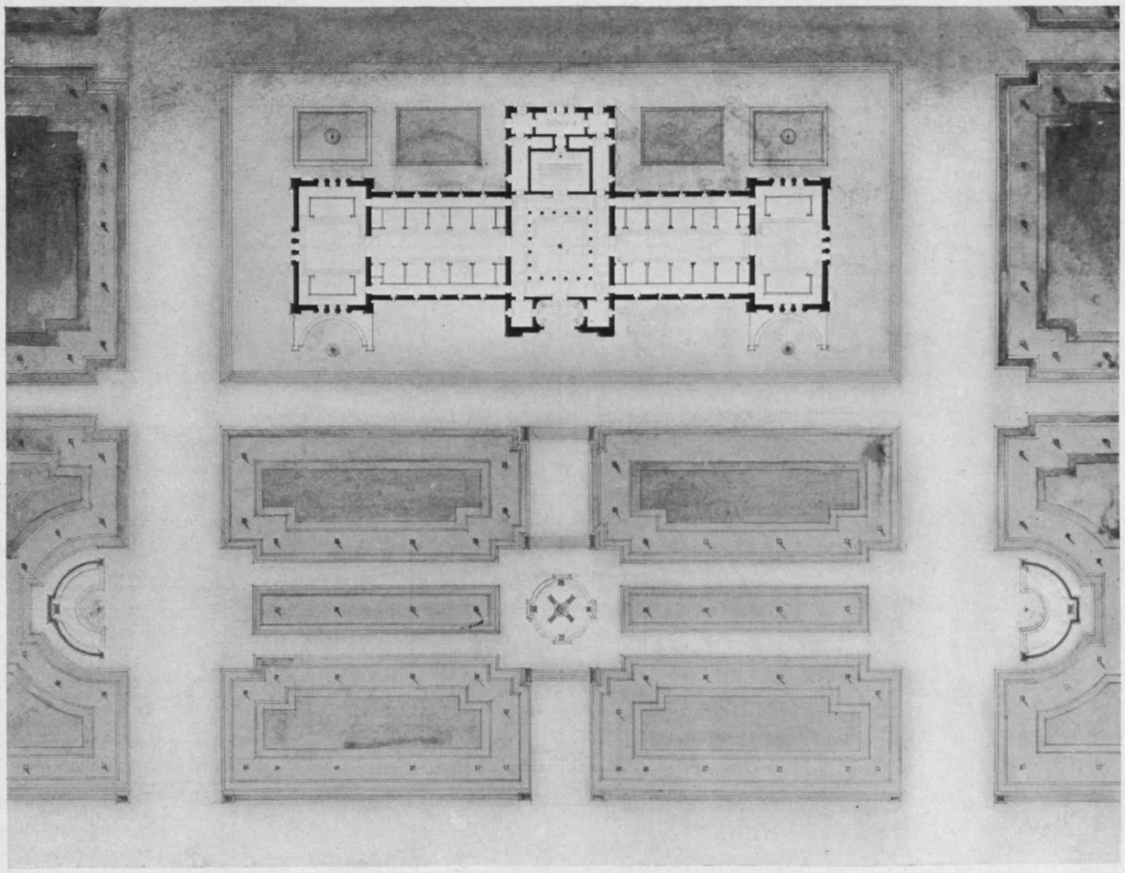


This building was designed for a lot of land with light only from the front below the fourth floor. Front and rear owned light above the fourth floor, side light sixth floor, and above only borrowed. Store floor to be used for demonstration of electrical appliances; to be high-studded; largest possible show-window, without taking floor-space. Building entrance to elevators and offices to be separate from the entrance to store. Appliance store to have a wide, attractive staircase to basement and second floor, that these two stories might be added to the store. Third story to be used as a library and lecture-room for heads of departments and clerks. Structural columns of the building so located as to give the least obstructed view of the stage and for the use of lantern-slides. The division of the offices to best suit the needs of the different departments.

EDISON BUILDING, BOSTON WINSLOW, BIGELOW ('88) & WADSWORTH ('04), ARCHITECTS

Whidden & Co., Inc., General Contractors

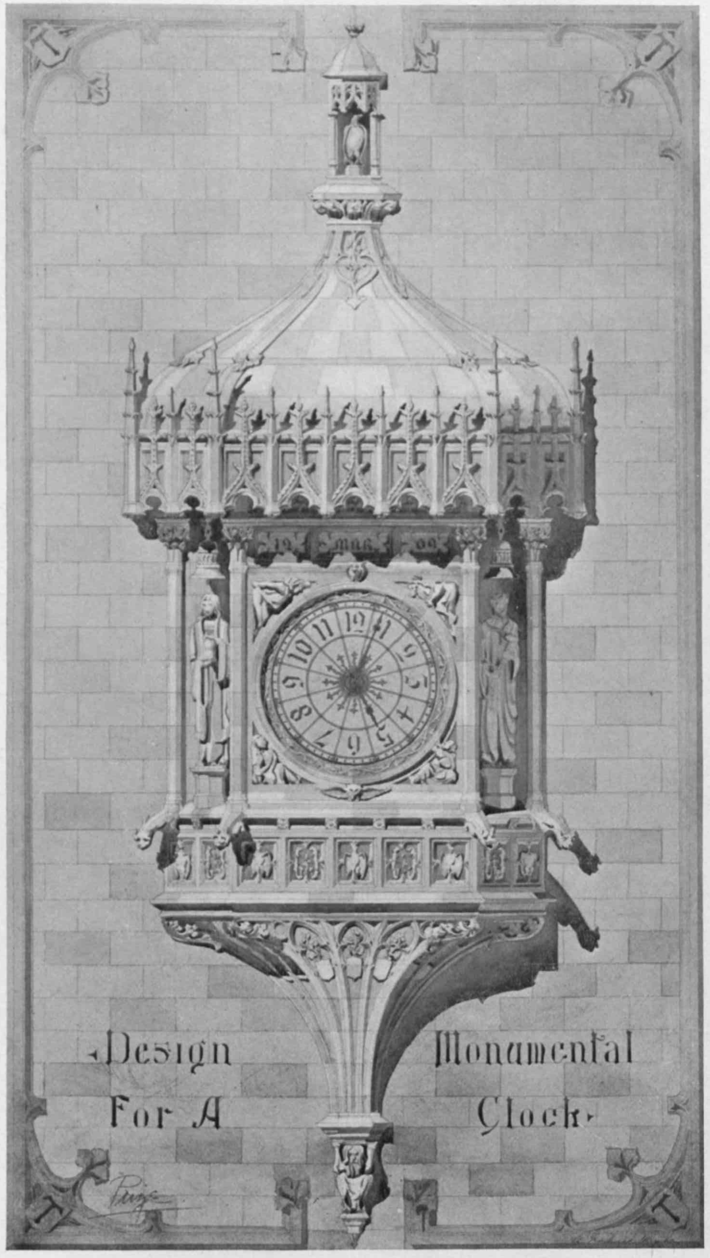




Second Year of Design

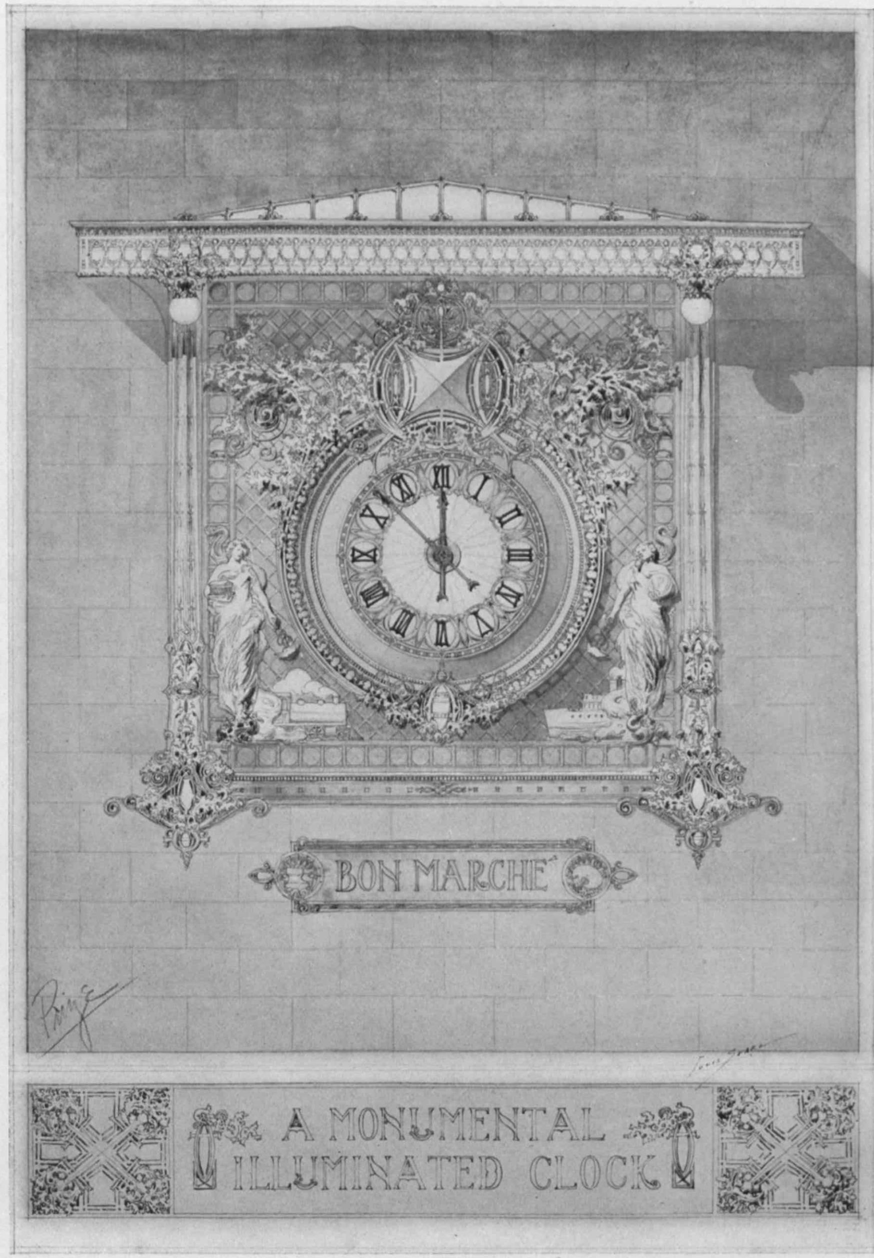
A SMALL ZOO

FIRST MENTION, J. H. SCARFF



PRIZE DESIGN FOR REGULAR STUDENT

A. F. MENKE

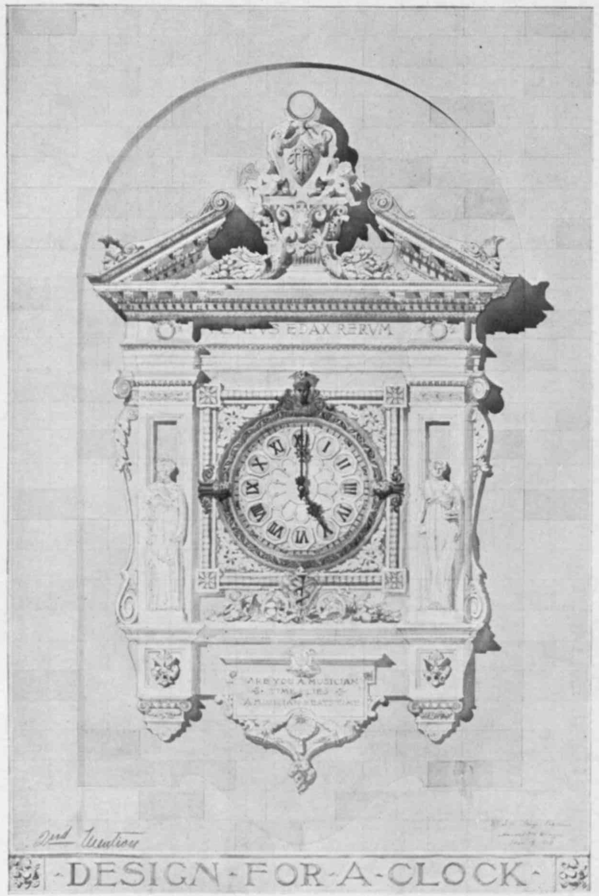


PRIZE DESIGN FOR SPECIAL STUDENT

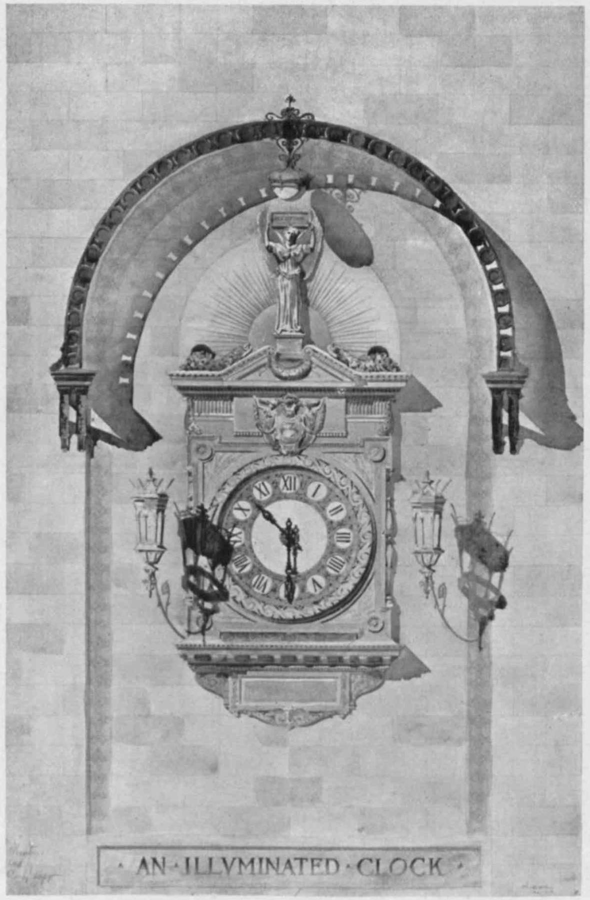
L. SVARZ

Competition for the Boston Society of Architects' Prizes

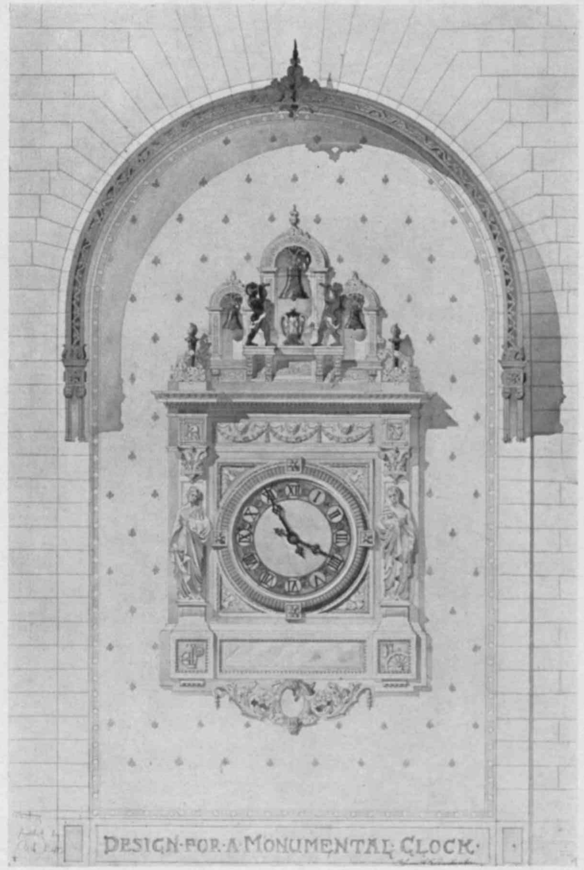
A MONUMENTAL CLOCK



MENTION, H. M. GLAZIER



MENTION, L. H. KING



MENTION, K. E. CARPENTER

Design

AWARDS FOR SECOND TERM, 1908-1909

Advanced Design

A RESIDENCE FOR THE LEGATION OF A FOREIGN POWER AT WASHINGTON

First mention: J. T. MOHN.
" " R. KIBBEY.
" " E. I. WILLIAMS.
Second mention: C. F. BAKER.
" " C. C. FORD.

A BORDER BRIDGE

First mention: R. KIBBEY.
" " C. C. FORD.
Second mention: J. T. MOHN.
" " E. I. WILLIAMS.

A UNION ACCOMPANIED BY DORMITORIES

(1909 Traveling Fellowship)

Prize: R. J. BATCHELDER.
First mention: J. T. MOHN.
Second mention: R. KIBBEY.
Honorable mention: H. D. CHANDLER.

Third Year of Design

A MONUMENTAL CLOCK

(Boston Society of Architects' Prize)

Regular Students

Prize: A. F. MENKE.
First mention: T. H. ATHERTON, JR.
Second " H. M. GLAZIER.
Third " W. A. MEANOR.
Fourth " C. J. BROWN.

Special Students

Prize: L. SVARZ.
First mention: W. P. BLODGET.
Second " B. R. KIMBERLEY.
Third " J. S. DEAN.
Fourth " V. E. SEIBERT.

AN ALTAR

(Sketch Problem)

No first mention.
Second mention: L. SVARZ.

AN EPISCOPAL CHURCH OF MODERATE SIZE

(For special students only)

First mention: K. E. CARPENTER.
" " T. F. STARK.
" " L. SVARZ.
Second mention: S. H. ALLEN.
" " W. P. BLODGET.

A SUMMER HOTEL

(For special students only)

Mention: K. E. CARPENTER.

Second Year of Design

A BRIDGE

First mention: H. S. GERITY.
" " W. E. HAUGAARD.
" " R. H. HANNAFORD.
Second mention: F. A. GODLEY.
" " W. S. DAVIS.

A SMALL ZOO

First mention: J. H. SCARFF.
" " F. A. GODLEY.
" " C. C. CLARK.
" " W. S. DAVIS.
Second mention: W. E. HAUGAARD.
" " W. H. MARCH.
" " J. E. KELLEY.
" " H. S. GERITY.

A FLORIST'S SHOP

(Sketch Problem)

First mention: J. E. BARNARD.
" " W. S. DAVIS.
" " H. S. GERITY.
" " W. H. MARCH.
" " J. H. SCARFF.
Second mention: L. A. DOW.
" " D. W. SOUTHGATE.
" " R. H. HANNAFORD.
" " P. W. BURNHAM.

A LAW LIBRARY

First mention: J. H. SCARFF.
" " C. C. CLARK.
" " W. E. HAUGAARD.
" " W. S. DAVIS.
" " H. S. GERITY.
Second mention: F. A. GODLEY.
" " W. H. MARCH.
" " D. W. SOUTHGATE.
Third mention: B. M. PETTIT.
" " A. VOGEL.
" " R. D. JOHNSON.

AN ARMORY

Mention: H. S. GERITY.
" J. H. SCARFF.
" W. S. DAVIS.
" F. A. GODLEY.

Graduates of the Class of 1909

Degree of Master of Science

TITLE OF THESIS

MISS MABEL KEYES BABCOCK, S.B.
with EDGAR IRVING WILLIAMS, S.B.
Design for a Summer Resort in the Mountains, Designed Especially for Those Interested in Aviation.

CECIL FRANKLIN BAKER, S.B.

RALPH JOHNSON BATCHELDER, S.B.

WILLIAM FREDERIC DOLKE, JR., S.B.

RINKER KIBBEY, S.B.
Design for a Technology Union, Accompanied by Dormitories.

Degree of Bachelor of Science

TITLE OF THESIS

THOMAS HENRY ATHERTON, JR.
Design for a Club-house to be Built in a University Town.

JOHN CARLISLE BOLLENBACHER
Structural Design for a Small Office Building in Reinforced Concrete, with Special Reference to the Column and Beam Connections.

HAROLD DU PRÉ BOUNETHEAU
Design for the Official Residence of the President of the United States.

CLARENCE JAY BROWN
Design for a Museum for Greek Antiquities.

FELIX ARNOLD BURTON
Design for a Large Department Store, in which an Arcade Is the Principal Feature, to be Erected on the Site of the Park Square Station in Boston.

MONTAGUE FLAGG
Design for a Yacht Club on Long Island Sound.

HAROLD METCALF GLAZIER
Design for a Railroad Terminal Station.

ALFRED GALPIN KELLOGG
Design for a Memorial Hall for a Small University.

LESTER HAZEN KING
Design for a Ferry and Railroad Terminal Station.

HELEN McGRAW LONGYEAR
Design for a Villa in the Roman Style to be Built in the Southern Part of the United States.

FLORENCE HOPE LUSCOMB
Design for a Country Seat by the Sea.

THOMAS GRESHAM MACHEN
Design for a Memorial Building for a University, to Combine Memorial Hall, Dining-hall, and Union.

WILBUR ALPHEUS MEANOR
Design for a City Hall for Boston.

ALVIN FREDERICK MENKE
Design in the Gothic Style for a University Library.

HENRY EARLE MYERS
Design for a Reinforced Concrete Arch for a Highway Bridge.

LAHVESIA PAXTON A. PACKWOOD
Design for a Concrete House to be Built in a Southern Climate.

FRANK WELLER SHARMAN
Design for the New Site of the Institute of Technology on an Island in the Charles River Basin.

REBECCA HULL THOMPSON
Design for a School Chapel in the Gothic Style.

Special Students

FIFTH YEAR

HENRY DALAND CHANDLER
JOSEPH THEOPHILE MOHN
CHESTER COOK FORD

FOURTH YEAR

SAMUEL HOLLIDAY ALLEN
WILLIAM POWER BLODGET
KENNETH EARLE CARPENTER
BURTON RUSSELL KIMBERLEY
VICTOR ELMER SEIBERT
FRANK RONALD SIMMONS
THEODORE FISKE STARK
LOUIS SVARZ

The Architectural Society

1909–1910

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THE plans of the Architectural Society for the present year contain no very radical changes, it being the intention of the officers to improve the old customs and activities of the Society in detail rather than in the whole. The one change worth noting is in the policy adopted by the entertainment committee of inviting all former members of this Society and members of the Boston Architectural Club to attend the monthly smokers. The contact between the students and the young architects will be stimulating and will react for good in their common work. The Society is very fortunate in having on its list of speakers for the coming year the following well-known men: Mr. D. H. Burnham, of Chicago; Messrs. G. Aus, C. Gilbert, T. Hastings, H. Hornbostel, B. R. Long, and L. E. Smith, of New York; J. R. Freeman, of Providence; Prof. H. C. Clifford, of Harvard University, and Mr. F. Dike, of M. I. T.

Mr. Daniel H. Burnham, of Chicago, gave the first smoke talk of the year to the Architectural Society in the lecture-room of the Department Wednesday evening, October 21. He used the present plans for the beautifying of the city of Chicago as the illustration of a discussion of city planning from the humanistic as well as from the æsthetic point of view. As a member of the commissions which have been charged with the reconstruction of the cities of Washington, Cleveland, Chicago, San Francisco, and Manila, P. I., Mr. Burnham was able to discuss fully the individual problems of the several cities, and to elucidate the general principles of city planning. He illustrated his talk with a great wealth of colored lantern-slides, many of them of the splendid drawings made by Guerin.

Beginning with the World's Fair at Chicago, in 1893, as the event which brought to the minds of the American people the necessity for civic improvements, Mr. Burnham cited this exposition as an example of what a group of architects and artists, working together impartially and unselfishly, with an eye only to the ultimate success of the whole, can produce in the way of a beautiful and harmonious group. With this introduction, he discussed the plans for Washington, Cleveland, San Francisco, and Manila, with many illuminating explanations of the problems there met and solved. Chicago, however, furnished the bulk of the subject-matter of the talk, and was made exceedingly interesting because of the complexity of the problems that had to be solved in perfecting a plan covering an area of seven hundred square miles.

Two points Mr. Burnham especially emphasized. The one was recognition of the fact that the best citizens, in point of health and efficiency, are those who are in daily contact with nature. Attention was called to the ideas of the ancient Greeks on this subject, with especial reference to the laws of Lycurgus and the customs of the Spartans. Consequently, the Chicago plan arranges for wooded parks and boulevards in close proximity to the more thickly settled portions of the city, in addition to the parkway along the lake front. The other point was that a city, whether a commercial center or not, if beautified in its arrangement and its architecture, becomes a center of society, of art, of education; in brief, a center where people go to enjoy themselves and to spend their money. Paris was cited as a shining example of this idea of modern times, and Mr. Burnham told how Pericles, when Athens began to lose its commercial standing, spent all the energy and funds of the Athenian allies in beautifying the city, thus making it the social and educational center of the world. Chicago believes that it can be both a commercial and a social center; and whether the hope can be realized or not, the city intends that its people shall live in wholesome and uplifting surroundings.

W. F. DOLKE, JR.

(*Continued from page 3*)

Mr. D. A. Gregg, the well-known expert in architectural rendering, who has served the Department most loyally during the twenty-two years he has been an instructor, has just presented the school with a beautiful pencil drawing made by him from one of Henry Bacon's Assos sketches. It is a welcome addition to our gallery.

(*Continued from page 7*)

is true to a lesser degree in the case of v_0, whereas the differences are not so marked in the case of σ_0.

27. It also seems hopeless to obtain a reliable deflection formula without taking into account the tension in the concrete.

28. Of course the computations are more easily made when A is used rather than B or C, but in the cases of B and C the complexity is not so great when designing a beam as when determining the stresses in a given beam under a given load.

Building-Materials

(Continued from Vol. II, No. 2)

Limes, Cements, Mortars, and Concretes

[These notes were prepared for the students in the Department of Architecture, to serve as a text in a short course of instruction in the classroom. Many authors have been consulted and often copied literally; and as a list of the most important will be given at the end of this article, it has not seemed necessary always to make direct mention of them in the text.— ED.]

The Board of United States Engineers appointed by the authority of the Secretary of War presented a report on June 6, 1901, on "Testing Hydraulic Cements, with Specifications for the Several Classes Used by the Engineering Department." This report, with that of the American Society of Engineers on "Uniform Tests of Cements," presented at the annual meeting Jan. 21, 1903, and amended at the annual meeting Jan. 20, 1904, gives the results of long labor by a thoroughly representative body of experts, covering every field from the manufacturer to the consumer; they stand for the very best thought on the subject.

Some differences are to be noticed in the two reports. In that of the Civil Engineers, the method of preparing the briquettes for testing requires the mold to be filled at once, and the material to be pressed in firmly with the fingers, etc., as already explained. The report of the Army Engineers says:

"Fill the mold with consecutive layers of cement, each when rammed to be one-fourth of an inch thick. Tap each layer thirty taps with a soft brass or copper rammer weighing one pound and having a face three-fourths of an inch diameter, or seven-tenths of an inch square, with rounded corners. The tapping or ramming is to be done as follows: while holding the forearm and wrist at a constant level, raise the rammer with the thumb and forefinger about half an inch and then let it fall freely, repeating the operation until the layer is uniformly compacted by thirty taps. This method is intended to compact the material in a manner similar to actual practice in construction, when a metal rammer is used weighing thirty pounds, with circular head five inches in diameter falling about eight inches upon layers of mortar or concrete three inches thick. The method permits comparable results to be obtained by different observers.

"After filling the mold and ramming the last layer, strike smooth with the trowel, tap the mold lightly in a direction parallel to the base plate to prevent adhesion to the plate, and cover for twenty-four hours with a damp cloth. Then remove the briquette from the mold and immerse it in fresh water, which should be renewed twice a week for the specified time if running water is not available for a slow current. If molds are not available for twenty-four hours, remove from the molds after final set, replacing the damp cloth over the briquettes. In removing the briquettes before hard-set great care should be exercised. Hold the mold in the left hand, and, after loosening the latch, tap gently the sides of the mold until they fall apart. Place the briquettes face down in the water-trough."

This report besides contains a specification for Puzzolan or Slag cement.

In preparing material with which to make tests, after sampling comes the test of fineness, which we have already considered. Next comes that of specific gravity, which when properly made gives not only a quick check for underburning, but of adulteration of Portland cement, most likely to be practised and most to be feared. The specific gravity of a high-grade Portland cement thoroughly dried at 100° C. or 212° F. should not be less than 3.05. If underburned the specific gravity may fall below 3; it may reach 3.5 if the cement has been overburned. Properly burned Portland adulterated with Puzzolan will fall below 3.1. No other hydraulic cement is so heavy in proportion to volume, Natural cement having a specific gravity of about 2.5 to 2.8, and Puzzolan of about 2.7 to 2.9.

The Civil Engineers recommend for this test the use of the Chatelier apparatus as being the most convenient.

The use of a proper percentage of water in making the cement paste from which pats, tests of setting, and briquettes are made, is exceedingly important and affects vitally the results obtained. The determination of this percentage consists in measuring the amount of water required to reduce the cement to a given state of plasticity, or to what is usually designated "the normal consistency." It is usual to measure arbitrarily the beginning and the end of the setting by the penetration of weighted wires of given dimensions.

The Civil Engineers' report recommends the use of the Vicat Needle Apparatus for making this determination. The Vicat needle has a diameter of 1 mm. (0.39 in.) at its lower end, and at the upper has a weight of 300 grams (10.58 oz.). This needle is gently lowered on the paste. The setting is said to have commenced when the needle no longer penetrates the mass, and to have terminated when the needle no longer makes an impression on it.

The Gilmore wires are also in general use in this country. One of these wires is one-twelfth of an inch in diameter, and is loaded to weigh one-fourth pound; the other is one twenty-fourth of an inch, and loaded to weigh one pound.

"Initial set" is said to have taken place in the cement paste when the light wire no longer makes an impression on the surface, and "end of set" when the same happens with the heavy wire.

The quantity of material to be mixed at one time in preparation for testing depends upon the number of test pieces to be made. 1,000 grams (35.28 oz.) makes a convenient quantity to mix, especially by hand methods, which thus far have been found to be the best.

The quantity of water, as well as its temperature, affects the results of tests so that the time of setting can be only approximate. The temperature and humidity of the air during the test, the amount of molding the paste receives, must all be carefully considered. The Army Engineers in their report recommend a drier mixture than other authorities, and it may therefore be taken as representing the minimum quantity.

In general, the Army Engineers' report says, about four briquettes constitute the maximum number that may be made well within the time required for initial setting of moderately slow-setting cements, and for these four is recommended the following proportions of water, etc. Water is measured by fluid-ounce volumes, not by weight, temperature varying not more than ten degrees from 62° F.

PORTLAND CEMENT.

Neat: 20 ounces of cement, 4 ounces of water. Mix wet five minutes.
Sand: 15 ounces sand, 5 ounces cement, $2\frac{1}{2}$ ounces water. Mix thoroughly dry; then mix wet five minutes.

PUZZOLAN CEMENT.

Neat: 20 ounces cement, $3\frac{3}{4}$ ounces water. Mix wet five minutes.
Sand: 15 ounces sand, 5 ounces cement, 2 ounces water. Mix thoroughly dry; then mix wet five minutes.

NATURAL CEMENT.

Neat: 20 ounces cement, 6 ounces water. Mix wet five minutes.
Sand: 10 ounces cement, 10 ounces sand, $3\frac{1}{2}$ ounces water. Mix dry; then mix wet five minutes.

For sand tests is used the proportion 1 cement to 3 sand for Portland and Puzzolan cements, and 1 cement to 1 sand for Natural or Rosendale cements, with the following percentages:

Portland cement or Puzzolan, neat	20% of water by weight
1 cement; 3 sand	$10\frac{1}{2}$% to 12% of water by weight
Puzzolan cement, neat	18% of water by weight
1 cement; 3 sand	9% to 15% of water by weight
Natural cement, neat	30% of water by weight
1 cement; 1 sand	15% to 17% of water by weight

The report claims that nearly all this water is retained by Portland cement, whereas only about one-third of the gauging-water is retained by Puzzolan or Natural cements; from this it follows that an apparent condition of plasticity or fluidity that ultimately little injures Portland paste very seriously injures Puzzolan or Natural mortars and concretes by leaving a porous texture on the evaporation of the surplus water, and mixtures that at first appear too dry for testing-purposes become more plastic under the prolonged working required therein.

THE USES OF MORTAR. Mortar is used to bind all parts of masonry together, and to form such a cushion between the horizontal courses of brick or stone as to insure an even distribution of pressure, however uneven the faces of the material may be. The thickness of this bed of mortar need only be such as to prevent any part of the "beds" and "builds" of the brick or stone from touching each other after the mortar is "set." The qualities for good mortar are that the "set" shall be simultaneous throughout its mass, and at the same time that there shall be no shrinkage. These qualities depend on the materials used, their proportions and method of mixing.

WHY SAND IS USED IN MORTARS. Sand is used in lime mortars to prevent shrinkage, so excessive when rich limes are used, and for the sake of economy; but as the cements do not shrink in hardening they make an excellent mortar without sand; still, for economy's sake, sand, and frequently both sand and lime, are combined with them.

The ordinary sands are simply in a state of mechanical mixture in the mortar; still, in the rich lime mortars they are indirectly in two ways a source of strength, for as the "set" of lime paste depends on its contact with air, the porous structure caused by the mixing of this sand with it allows the carbonic acid of the air to penetrate farther into the mass and so act upon a larger portion of the joint; and the hardening and strength of this mortar also depend in large part on the crystallization of the carbonate of lime around the grains of sand, by which these are made to cohere firmly.

QUALITY OF SAND. Hence it is of the utmost importance that the sand should be clean, else the lime will not cohere to it; and that the grains should be sharp and angular; and that the surface should not be polished, but rough. Very fine sand is not so good, as it prevents the air from penetrating. A coarse, irregular-grained sand makes the best mortar.

PIT SAND. Pit or bank sand is the best, as it has an angular grain and a rough, porous surface; but it often contains earthy impurities which must be washed out before the sand is used.

RIVER SAND. River sand is not so sharp or angular in its grit.

SEA SAND. Sea sand is also deficient in sharpness and grit; it also contains alkaline salts, which attract moisture and cause permanent damp and efflorescence.

EXAMINATION OF SAND. Clean sand should leave no stain when rubbed between the moist hands. Salts can be detected by the taste, and the size and sharpness of grain can be judged by feeling and the eye.

COMMON FAT LIME MORTAR. The proportion of ingredients in common lime mortar averages one measure of quicklime in lump, five to six measures of sand, according to the qualities of both lime and sand, and in slaking the quicklime to a paste two and one-half to three measures of water are usually added: thus, 1 barrel lime, 5 to 6 barrels sand, $2\frac{1}{2}$ to 3 barrels water.

Its value is in its cheapness and easy manufacture. It should never be used for damp situations or for thick walls. In either case it keeps constantly moist, and when used where it is able to dry it becomes friable, and in any case has no strength. In the "set" of lime only an outside crust is formed, and the moisture is retained in the inside; and in cold weather this inside mortar freezes and its expansion throws off the crust, and then pointing must be resorted to.

In hardening, lime mortar shrinks very much, and to help prevent this, as well as on the score of economy, the excessive amount of sand is added. Fat lime mortar should never be used when it is possible to do better, and on no account should it be used on important work.

By adding a proper amount of cement, however, to this lime a better mortar is made.

HALF-CEMENT MORTAR. Half-cement mortar is usually specified to have a barrel of Rosendale cement, about 280 pounds net, to each barrel of lime, about 230 pounds net. The proportion of sand to the above volume would be from seven to eight barrels; and of water, from three to four barrels.

It is unusual to specify the amount of water, as it varies with the quality of lime, sand, and cement, and in the absence of test, the quantity is usually left to the experience of the mixer; but the invariable rule should be that the mortar be as stiff as it can be spread.

Half-cement mortar is so generally used that if simply specified as such the above proportions would be understood by the best builders of the Eastern States. This mortar is strong when not exposed to wet. It may be used for cellar walls of country houses built on a dry soil, and any work above ground. However, cement is so cheap that it could be profitably substituted for ordinary masonry.

In "How to Use Portland Cement," translated from the German of L. Golinelli by Mr. Spencer B. Newberry, it says:

"There are many kinds of work which require a quick-hardening mortar, but for which the great strength of a mixture of one cement with one to four of sand is unnecessary. The cost of such mortar is also, for many purposes, too high. A mixture of cement with five or more parts sand would give abundant strength, but such mortar works too 'short' and adheres too imperfectly to the brick or stone; it cannot, therefore, safely be used.

"In such cases the addition of slaked lime or hydraulic lime will correct the faults of poor mixtures of cement and sand, and will produce a cheap mortar, suitable for a great variety of uses. The addition of slaked lime allows the full advantage to be obtained from the use of good Portland cement, and makes it possible for this material to compete in price with cheaper hydraulic materials. Used in this manner, Portland cement may be employed with economy for the most ordinary purposes. The advantages of Portland cement lime mortar are its cheapness in comparison with other hydraulic materials, its rapid hardening, marked hydraulic properties, great strength on exposure to air, and remarkable resistance to weather.

"The following mixtures for cement-lime mortar have been found by experience to be most suitable:

Cement	1	sand	5	lime paste	½
"	1	"	6 to 7	" "	1
"	1	"	8	" "	1½
"	1	"	10	" "	2¼

"The above proportions are to be taken by measure. Hydraulic lime may be used in place of ordinary slaked lime.

"Cement-lime mortar is prepared by making a dry mixture of the required quantities of cement and sand; milk of lime is then made with the necessary quantities of lime paste and water, and this milk of lime thoroughly mixed and worked in with the mixture of cement and sand.

"The great advantages of cement-lime mortar for a multitude of purposes deserve to be more widely recognized than they are at present."

(*To be continued in Vol. III, No. 2*)

(*Continued from page 3*)

A. N. Rebori, the holder of the 1908 Traveling Fellowship, has recently returned from Europe, bringing with him a very attractive lot of drawings made at the Beaux-Arts and at the American Academy in Rome, besides many sketches and rubbings. Such exhibitions as the one of Mr. Rebori's work just held in our gallery give the most striking evidence of the value of foreign travel and study. Mr. Rebori leaves with the Department a large measured drawing beautifully done in color from Raphael's Loggia in the Vatican.

This year the Rotch prize for the regular student having the best record during his four-years' course in architecture was awarded to L. H. King. The prize for the special student having the best record during his two-years' course was divided between K. E. Carpenter and L. Svarz.

Alumni Notes

The department is in receipt of many applications from architects and others for assistants. We have no information as to whether our alumni are satisfied with their present positions and prospects, consequently many opportunities for Institute men are doubtless lost.

The Secretary of the Institute will send application blanks to any of our former students who wish to register their names with the view of making a change whenever a suitable opportunity occurs.

Class of 1909

The following men have returned to the Institute for advanced work: H. D. Bounetheau, K. E. Carpenter, H. M. Glazier, A. G. Kellogg, L. H. King, F. R. Simmons; also K. Vonnegut, '08.

W. P. Blodget and T. F. Stark are with Guy Lowell, Boston, Mass.

J. C. Bollenbacher is in the Bridge and Building Department of the Chicago, Milwaukee & St. Paul R. R., Chicago, Ill.

C. J. Brown is with Shepley, Rutan & Coolidge, Chicago, Ill.

F. A. Burton is with Allen & Collens, Boston, Mass.

D. W. Gibbs, who has been with F. A. Bourne, '95, for the past year, has returned to the Institute to complete his course.

M. Flagg is with the firm Brocklesby & Smith, Hartford, Conn.

W. A. Meanor and D. W. Southgate, '11, are with Alden & Harlow, Pittsburg, Penn.

A. F. Menke is with Holabird & Roche, Chicago, Ill.

H. E. Myers is with the G. W. Carmichael Co., Akron, O.

D. W. Phelps has returned to the Institute to finish his course.

Miss M. K. Babcock, '08, is in Europe, continuing her study of landscape architecture.

H. H. Bentley, '08, is in the office of S. W. Mead, Boston, Mass.

V. J. Blackwell, '08, is in the office of Donaldson & Meier, Detroit, Mich.

H. D. Chandler, '08, is with Winslow, Bigelow & Wadsworth, Boston, Mass.

C. C. Ford, '08, is in the Chicago office of Shepley, Rutan & Coolidge.

R. Kibbey, '08, is traveling in Europe with R. J. Batchelder, '08, the holder of the 1909 Traveling Fellowship of the Department.

J. McGinniss, '08, is with Codman & Despradelle, Boston, Mass.

P. F. McLaughlin, '08, and V. E. Seibert, '09, have formed a partnership, with an office in Pittsfield, Mass.

J. R. Tabor, '08, has formed a partnership with C. P. Jones, under the firm name of Jones & Tabor, with offices in the Binz Building, Houston, Tex.

A. H. Tashjian, '08, has been appointed lecturer on Reinforced Concrete Construction during the second term at the Institute. He is, besides, a member of the firm Tashjian & Hall, Court Square Building, Portland, Me.

C. Youngerman, '08, is in the office of Grosvenor Atterbury, New York City.

C. F. Baker, '07, and F. B. Schmidt, '07, left early in October for Europe, to be gone at least a year.

Since our last issue the sad news has come to us of the death of Edward W. Hamill, which occurred at Los Angeles the thirtieth of last June. Mr. Hamill graduated at the Institute from the course in Architectural Engineering with the class of 1907. As a student he gave promise of a most successful career, but a severe illness from which he never fully recovered prevented him from taking an active position in his profession. By his quiet dignity and earnestness Mr. Hamill won many warm friends, who will learn of his death with deep sorrow.

In the last competition in "construction" at the École des Beaux-Arts the second medal was awarded to F. H. Haskell, '07; and the third medal, to C. Everett, '07.

A. T. Remick, '07, announces the removal of his office from 5 West 31st St. to 3 West 29th St., New York City.

H. A. Sullwold, '07, has resigned his position in the office of the Supervising Architect at Washington, D. C., and will locate at St. Paul, Minn.

The marriage is announced of E. S. Wires, '07, and Miss Helen Mead, June 22, at Milford, Mass.

G. H. Buckingham, '06, is in the office of the Supervising Architect, Washington, D. C.

The marriage is announced of W. C. Furer, '06, and Miss Mary E. Braly, September 7, at Honolulu.

G. Curtis Noble, '06, is with MacLaren & Thomas, Colorado Springs, Col.

The marriage is announced of W. W. Rasmussen, '06, and Miss Blanche G. Spinney, September 8, at Chicago, Ill.

C. Hartman K. Harris, '05, of Philadelphia, Penn., lost his life by drowning in the Charles River, Boston, last August. Harris was one of a party attempting to make a record swim between the B. A. A. float and Harvard Bridge. He was a strong swimmer, and it is believed that he was a victim of cramps. Harris left the Institute in 1903, the end of his second year, and had since then been devoting himself to painting. At the time of his death he was well known in Philadelphia art circles, and gave evidence of much promise in his work.

Miss Eliza Codd, '04, will spend the winter in Geneva, Switzerland.

H. S. Pitts, '04, has been traveling and studying in Italy during this past summer.

H. A. Whitney, '04, has been admitted to the firm of Whidden, '77, & Lewis, Portland, Ore., with whom he has been since leaving the Institute.

A. P. Wyman, '04, is practising landscape architecture, with offices in Chicago, Ill., and Minneapolis, Minn. He teaches also at the University of Illinois, and is secretary of the committee formed to organize the Illinois Outdoor Improvement Association.

In the recent competition for the Southborough library, in which there were 113 competitors, the second prize was awarded to Dennison and Hirons, '03; and the fourth prize, to L. B. Abbott, '99.

Z. N. Matteossian, '03, is in the office of Cass Gilbert, New York City.

W. A. Paine, '03, is in the office of Richards, McCarty & Bulford, Architects, Columbus, O.

The Rotch Traveling Scholarship for 1909 was awarded to H. G. Simpson, '03. The problem set for the competition was "An Official Summer Residence for the President of the United States," and the architects were permitted to assume that the residence was to be on Bellevue Avenue, Newport, R. I., with a plot of land behind it stretching to the water. Mr. Simpson's drawings were said by a member of the jury to be far ahead of those of all competitors.

The marriage is announced of R. B. Derby, '02, and Miss Margaret C. Philbrook, daughter of Mrs. Sumner J. Chadbourne, on June 2, 1909, at Augusta, Me.

G. B. Ford, '00, has a series of articles in *The Brickbuilder* on "The Housing Problem."

The marriage is announced of B. C. Hopeman, '00, and Miss Cornelia Wheeler, April 27, at Oak Park, Ill.

P. L. Price, '00, has been made chief engineer for George B. Post & Sons, Architects, 347 Fifth Ave., New York City, of which firm G. B. Ford, '00, is head designer.

H. L. Walker, '00, announces his association with B. S. King, formerly of the firm Whitfield & King, of New York City. The New York office will be in the Terminal Building, while that at Atlanta will be located in the Studio Building.

O. C. Hering, '97, has recently been elected a member of the American Institute of Architects, the Architectural League of America, and the Society of Beaux-Arts Architects.

L. T. Cannon, '96, is associated with R. Hansen, Architect, and A. P. Merrill, Engineer, in the design of a large gymnasium building, at Salt Lake City, for the Mormon Church, to cost $150,000. It is already under construction. He has also prepared preliminary plans for a Woman's Domestic Arts Building for the Agricultural College at Logan, and completed plans for a bank building at St. George, Utah.

S. E. Gideon, '06, besides being an instructor in mechanical drawing at the Institute, has an evening class in preliminary architectural design at the Boston Architectural Club.

G. F. Shepard, '96, announces that he is now associated with Mr. C. H. Blackall, at 20 Beacon St., Boston, Mass.

E. C. Lowe, '95, of the firm of Lowe & Ingram, was chosen president of the Chicago Architectural Club at its annual election.

A. T. Taylor, '95, has been commissioned to build a temple for the Jewish Society of Concord in Syracuse, N. Y., on which commission Mr. Arnold Brunner, '79, of New York City, is consulting architect.

C. W. Dickey, '94, and W. D. Reed, '08, announce their firm name to be Dickey & Reed. They have offices in the Balboa Building, San Francisco, and also in the Oakland Bank of Savings, Oakland, Cal.

John Scott & Co., of which firm W. Reed-Hill, '94, is a member, announce the removal of their offices to 1603–6 Ford Building, Detroit, Mich.

F. E. Perkins, '92, has the commission for a $50,000 mausoleum.

A recent San Francisco paper published an illustration of the proposed casino at Lake Merritt by E. P. Whitman, '92.

Julian Millard, '91, has recently finished a stone church at Philipsburg, Penn., and has two others under construction,— one at Williamsburg, Penn., the other at Hollidaysburg, Penn.

C. H. Alden, '90, formerly representing Howard & Galloway at the Alaska-Yukon-Pacific Exposition, announces that he has resumed independent practice, with offices at 606 Crary Building, Seattle, Wash.

In a competition offered by the magazine *Beautiful Homes*, the following Tech men won prizes: for plans and photographs for a house which did not cost over $4,500, J. W. Case, '89, received a prize of $100; for a house which did not cost over $6,000, H. K. Conklin, '99, received a prize of $150; for a house which did not cost over $10,000, W. D. Brown, '94, received a prize of $200.

Mauran, '89, Russell & Garden announce the dissolution of their firm. The present offices in the Chemical Building, St. Louis, Mo., will be maintained by Messrs. Mauran & Russell.

For the excellent architectural treatment of the Alaska-Yukon-Pacific Exposition much credit is given to the supervising architect, John G. Howard, '86. He was represented at Seattle by C. H. Alden, '90. Among the architects who contributed to the success of the Exposition were D. J. Myers, '90, J. F. Everett, '98, and W. J. Sayward, '01.

In a competition for a sketch plan for a model village made under the auspices of the Rhode Island Chapter of the A. I. A., the first mention was awarded to E. B. Homer, '85; second mention, to J. H. Cady, '06; and third mention, to J. H. Adams, '99.

In the recent *Brickbuilder* Competition for a Brick House, W. D. Austin, '76, won the first prize of $500; C. C. Clark, '10, won the third prize of $150; and Derby, '02, & Robinson, '99, received second mention. The competitive drawings are illustrated in the October *Brickbuilder*.

Edward H. Barnard, '74, died April 16, at Westerly, R. I., at the age of fifty-three. Mr. Barnard first studied architecture at the Institute, but later became a student at the Boston Art Museum. He then went to Paris as a pupil of Julian, and each year of his stay abroad he exhibited a picture in the Salon. Returning to America, he opened a studio in Boston, Mass.

G. Wilton Lewis, '74, has removed his office to 34 School St., Boston, Mass.

Current Work of the Alumni Illustrated in the Magazines

American Architect.

March	3,	Wood, Donn, '91, & Deming, Y. M. C. A. Building, Norfolk, Va., Prize-winning design.
"	3,	Taylor, '04, & Hepburn, '04, Y. M. C. A. Building, Norfolk, Va., Competitive design.
"	10,	Alden, '79, & Harlow, '78, Work of, in Pittsburg, Penn.
"	17,	Ross, '02, & MacFarlane, '98, School, Westmount, Canada.
April	21,	Bliss, '95, & Faville, '96, Columbia Theatre and Hotel St. Francis, San Francisco, Cal.

Architecture.

March,	Bosworth & Holden, '94, Bronx Church House, New York City.
"	J. K. Taylor, '79, Post-office, Annapolis, Md.
April,	Bosworth & Holden, '94, House, Oceanic, N. J.
May,	A. W. Brunner, '79, Post-office and Court-house, Denver, Col.

Architectural Record.

April,	F. E. Perkins, '92, Capital, San Juan, P. R.
May,	L. Boynton, '92, Houses, Cedarhurst, L. I.
"	Fernekes & Cramer, '96, House, Oconomowoc, Wis.
"	Ford, '89, Stewart, '00, & Oliver, '97, House, Lawrence, L. I.
"	J. A. Gurd, '95, House, Short Hills, N. J.
"	Parkinson & Bergstrom, '99, House, Los Angeles, Cal.

Architectural Review.

March,	Shepley, '82, Rutan, & Coolidge, '83, Library, Conway, Mass., and Harvard Medical School, Boston, Mass.
April,	J. F. Clapp, '99, Rotch Envoi Drawing, Luxembourg Gardens, Paris.
May,	Coolidge, '92, & Carlson, '92, Boston College Competition Drawings.

Brickbuilder.

March,	Hill & Woltersdorf, '94, Manufacturing Buildings, Chicago, Ill.
"	C. H. Johnston, '80, Manufacturers' Building, Minneapolis State Fair Grounds.
"	D. H. Perkins, '89, Public School, Chicago, Ill.
"	H. V. Shaw, '94, Lake Forest University Dining-hall, Lake Forest, Ill.
"	Tietig, '98, & Lee, '98, Factory, Cincinnati, O.
"	Vonnegut, '76, & Bohn, House, Indianapolis, Ind.
"	W. C. Zimmerman, '81, House, Lake Forest, Ill.
April,	Cass Gilbert, '80, High School, Madison, Wis.
"	Hartwell, Richardson, '75, & Driver, State Normal School, Bridgewater, Mass.
"	Parker, '95, Thomas, '95, & Rice, '91, Hebrew Orphan Asylum Gymnasium, Baltimore, Md.
"	Ripley, '91, & Russell, Wheaton Seminary Dining-hall, Norton, Mass.
"	Stratton & Baldwin, '92, St. Francis Home for Orphan Boys, Detroit, Mich.
May,	Ewing, '97, & Chappell, Georgetown University Gymnasium, Washington, D. C.
"	C. H. Johnson, '80, House, St. Paul, Minn.
"	MacClure, '94, & Spahr, '96, Oliver Building, Pittsburg, Penn.
"	A. F. Rosenheim, '81, House, Los Angeles, Cal.
"	Wyatt, '72, & Nolting, St. John's College Gymnasium, Annapolis, Md.