CALIBRATION OF A BEAM TESTING MACHINE

THESIS FOR DEGREE OF B. S.

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A Thesis

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by

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THESIS

The fire which destroyed the Engineering Hall and shops on March 5, 1916, also destroyed all the departmental equipment. The most necessary articles where replaced as soon as possible in order that the college work might continue.

One of the things which was not replaced at once was a machine for testing beams. In 1919, H.H.Hiembaugh and R.L.McGaw, senior students at the college, decided to build a beam testing machine to take the place of the one destroyed by the fire.

The work was done as a Thesis under the supervision of the Civil Engineering Department.

The machine is composed of a reinforced concrete base, 16 feet long, 26 inches high, and 26 inches wide, which supports two hydraulic jacks. The pressure is applied by a commercial hand force pump with a one inch plunger. It is connected to the jacks by a 3/4 inch flexible copper pipe to provide for varying the span between the jacks by allowing them to be moved. The pressure is measured by a gauge placed in the pipe line at the pump.

Through the center of the base beam are four steel rods 1 1/4 inches in diameter, threaded and designed to carry the load by tying the standard beam to the base beam. The pressure is distributed by two 3" x 12" x 18" cast iron plates, one placed beneath the base beam, the other placed at the top above the beam to be tested. The upper place has a knife edge attached beneath it by a half inch machine bolt. The upper plate is supported by two nuts placed beneath it at opposite corners.

Although this machine was completed in 1919 it has never been calibrated so that it could be used to advantage. For this reason the writers decided to calibrate the machine so it might be used for testing beams in the future. The manner in which this was done follows:

Standard Notation

E = Modulus of elasticity of steel.

P = Total load at the center.

I = Moment of Inertia.

S = Section modulus.

l = length of beam.

Y = Maximum deflection.

C = $\frac{h}{2}$

h = Height of beam.

If P = load at the middle then each reaction is $\frac{P}{2}$ and the moment from the left end to the middle is $\frac{PX}{2}$. For the portion of the beam between the left end and the middle

$$E I \frac{d^2y}{dx^2} = \frac{PX}{2}$$

$$E I \frac{dy}{dx} = \frac{PX^2}{4} + C_1$$

At the middle from the symmetry of the sides,

$$\frac{dy}{dx} = 0$$

$$\therefore \quad C_1 = -\frac{Pl^2}{16}$$

$$E I \frac{dy}{dx} = \frac{Px^2}{4} - \frac{Pl^2}{16}$$

$$E I y = \frac{Px^3}{12} - \frac{Pl^2x}{16} + C_2$$

At the left support where

$$X = 0, \quad Y = 0$$

$$\therefore \quad C_2 = 0$$

$$E I y = \frac{Px^3}{12} - \frac{Pl^2x}{16}$$

At the middle where $x = \frac{l}{2}$

$$Y \max = \frac{Pl^3}{96 E I} - \frac{Pl^3}{32 E I}$$

$$Y \max = -\frac{Pl^3}{48 E I}$$

A 7 inch - 15# I-Beam was selected as a speciman for testing.

Length - 9 feet - 0 inches.

Total weight = 135#.

E = 30,000,000.

I (from Carnegie handbook) = 36.2.

S = 10,000#

From strength of materials

$$\frac{S\ I}{C} = \frac{P}{2}\ \frac{l}{2}$$

$$P = \frac{4\ S\ I}{l\ C}$$

Substituting the above values

$$P = \frac{4 \times 10{,}000 \times 36.2}{9 \times 12 \times 3.5} = 4{,}000\# -$$

$$Y_{max} = -\ \frac{Pl^3}{48\ E\ I}$$

$$= \frac{(4000)\ (108)\ (108)}{(48)\ (30{,}000{,}000)\ (36.2)} = .07'' +$$

From these calculations it is seen that the maximum deflection that the beam will stand without permanently deforming it is about .07 of an inch.

The beam was placed on the Rhiele testing machine in the mechanical engineering laboratory which is accurately calibrated and capable of exerting a pressure of 100,000 pounds. The accompanying picture figure # 1 shows how the beam rest on the machine.

A dial gauge reading to one thousandth of an inch was placed under the center of the beam and pressure applied. The results are shown below.

Load	Gauge Reading in thousandths of an inch.
220#	.041
450	.048
650	.053
790	.0576
1060	.065
1310	.072
1600	.0805
1860	.088
2100	.0951
2370	.1028
2650	.1105

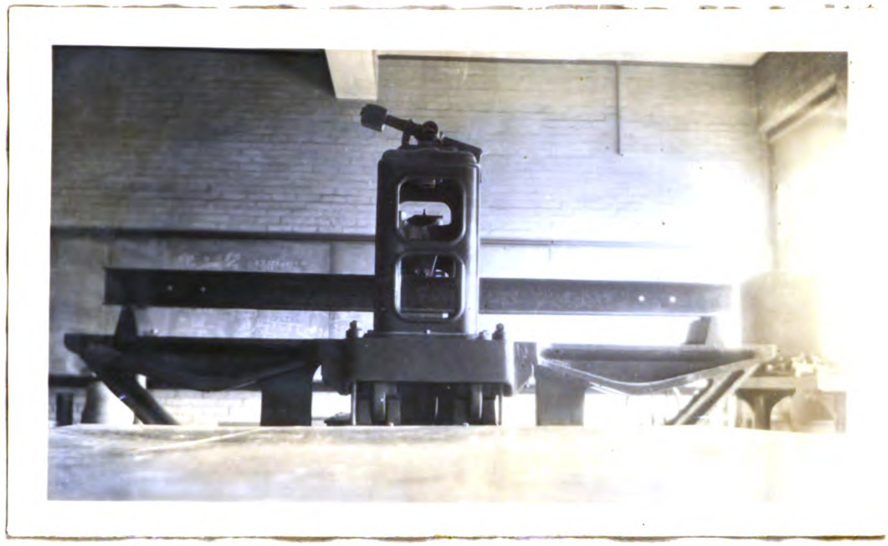


FIG. 1

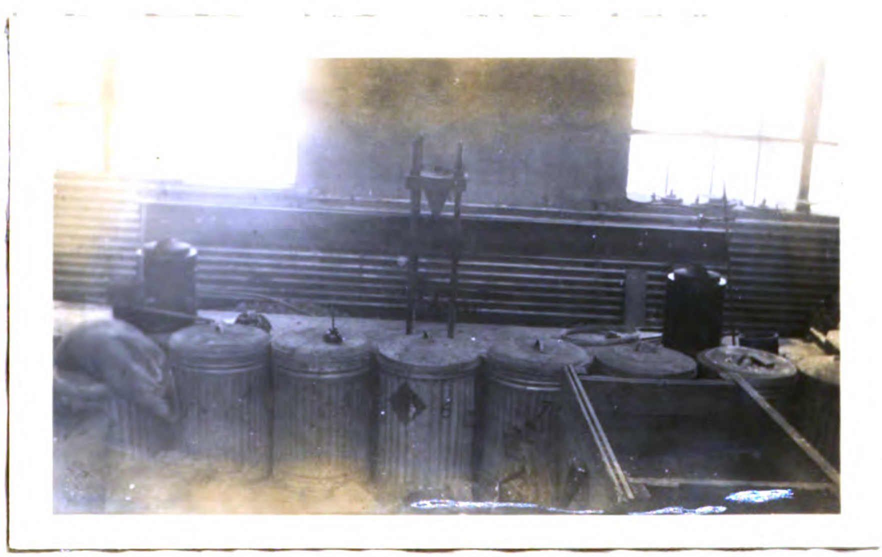


FIG. 2.

These results were plotted on graph paper as shown by graph # 1.

The same beam was carried to the machine to be calibrated, using the same span. The beam was placed on the machine as shown by the accompanying photograph, Fig. # 2.

The first machine in which we tested the beam was so arranged that the end reactions were stationary and the load applied at the center deflected the beam at the center. In the machine which we are calibrating the lay-out is just the opposite. The two hydraulic jacks which form the end supports are raised by oil pressure applied through the pump while the center is held stationary. The results are the same. Two dial gauges reading to one thousandth of an inch were used. Directly over the hydraulic jack on each end a gauge was arranged so that any upward movement of the jack was registered on the dial gauge. A series of tests were run and the averages of the whole lot were plotted on graph paper. Several of the tests are shown below.

Gauge Reading #/sq"	Test #1 Dial #1	Test #1 Dial #2	Test #2 Dial #1	Test #2 Dial #2	in 1/1000 " Average	in # Applied Pressure
0	0	0	0	0	0	0
1	.004	.005	.004	.005	.0045	145
2	.008	.009	.009	.009	.0090	290
3	.012	.013	.012	.013	.0125	415
4	.016	.017	.017	.017	.0170	560
5	.021	.022	.021	.022	.0215	700
6	.025	.026	.025	.026	.0255	845
7	.030	.030	.030	.030	.0300	985
8	.030	.039	.034	.034	.0350	1155
9	.038	.040	.039	.040	.0395	1300
10	.044	.044	.042	.045	.0440	1445
11	.047	.047	.048	.049	.0480	1585
12	.052	.053	.051	.054	.0525	1720
13	.056	.058	.056	.057	.0565	1865
14	.060	.061	.058	.061	.0600	1990
15	.064	.065	.065	.066	.0650	2140
16	.068	.069	.067	.070	.0685	2260

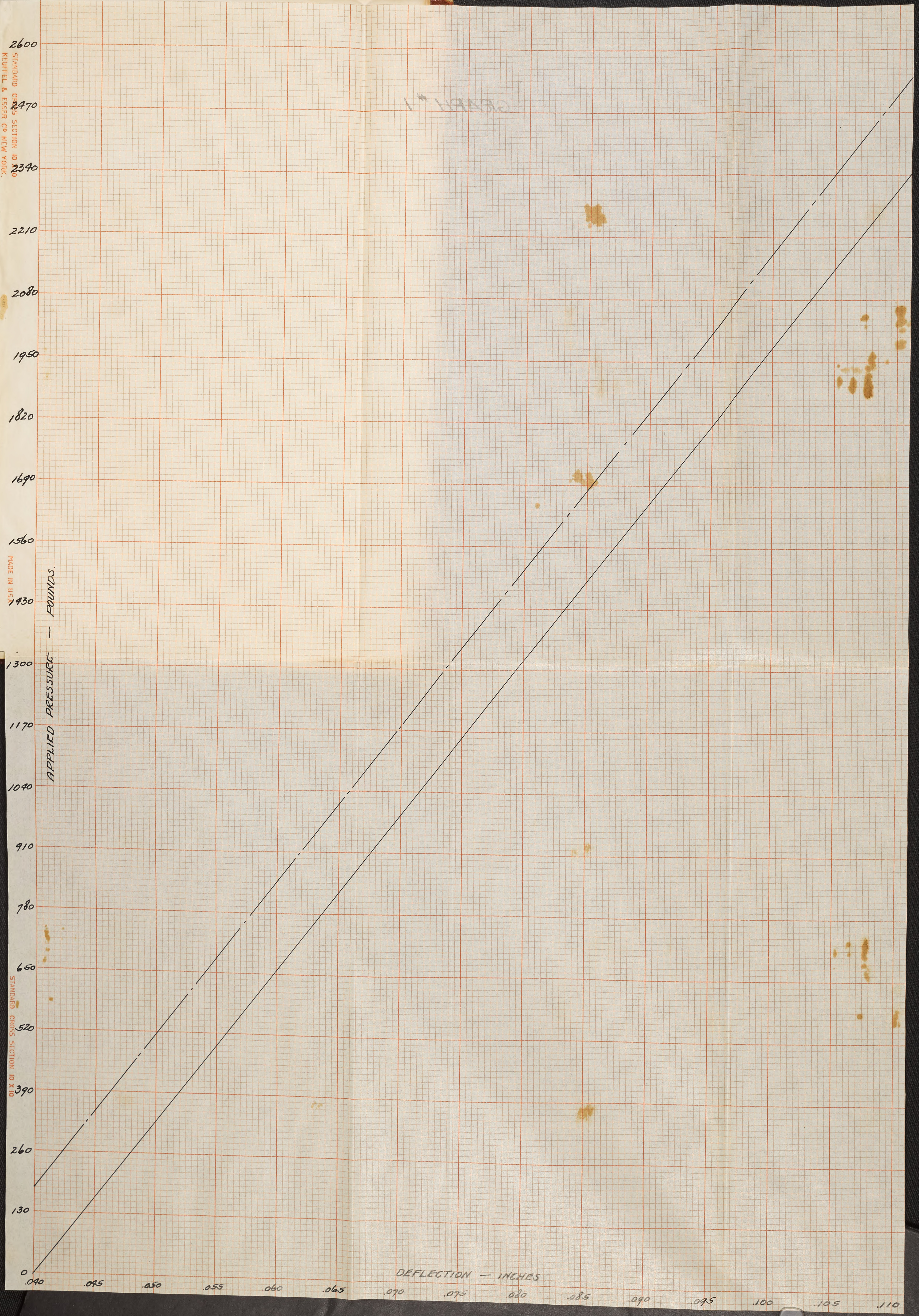
Graph # 2 shows the results of these tests.

The applied pressure upon any beam may be determined by noting the gauge pressure and finding the corresponding applied pressure from this graph.

Explanation of Graph # 1.

The results of tests run on the beam testing machine in the basement of Old's Hall are plotted in Graph # 1. The deflection in inches of the beam are plotted against the corresponding applied pressures in pounds. This machine being assumed as accurate, it was used as the basis of results employed in furthere tests on the machine which was to be calibrated. From this graph can be found the deflection due to a certain pressure or the pressure necessary to produce any given deflection. The method of such determining is easily understood at a glance at Graph # 1.

Graph # 1 is a straight-line function and was translated to the origin, as shown.



STANDARD CROSS SECTION 10 X 10
KEUFFEL & ESSER CO NEW YORK.
MADE IN U.S.A.
STANDARD CROSS SECTION 10 X 10
APPLIED PRESSURE — POUNDS.
2600
2470
2340
2210
2080
1950
1820
1690
1560
1430
1300
1170
1040
910
780
650
520
390
260
130
0
DEFLECTION — INCHES
.040
.045
.050
.055
.060
.065
.070
.075
.080
.085
.090
.095
.100
.105
.110

Explanation of Graph # 2.

As the tests were being run on the beam testing machine in the Cement Laboratory, the deflections of both ends of the beam and the gauge reading were noted simultaneously, as shown by the accompanying table. The average of the end-deflections was then taken for a number of trials. From Graph # 1 the applied pressure in pounds was found corresponding to this average end deflection. This applied pressure in pounds was then plotted against the corresponding gauge pressure. These values comprise Graph # 2. Knowing the gauge reading in pounds per square inch, the applied pressure may be found by referring to Graph # 2, a simple, straight-line graph.

GRAPH #2.