Glassco & Allen

Value of Concrete for Reinforcing Steel I Beams

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VALUE OF CONCRETE
FOR
REINFORCING STEEL I BEAMS

...BY...

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and
Arthur William Allen

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN ARCHITECTURAL ENGINEERING

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ARTHUR WILLIAM ALLEN and PAUL BOND GLASSCO

ENTITLED VALUE OF CONCRETE FOR REINFORCING STEEL I BEAMS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Architectural Engineering.

N. Clifford Ricker

HEAD OF DEPARTMENT OF Architecture

These experiments were made to determine the relative strength of I-beams, reinforced with crushed rock, cinder and gravel concrete, to the naked beam; also to determine the effect of continuous loads on reinforced I-beams.

The tests were made in the following manner:- Six 8"-17.75# I-beams, 14'-0" long and two 10"-25# I-beams, 16'-0" long were used. The naked beams were tested first. The loads were applied equally at the third points of the beam, producing a constant bending moment between points of application. Loads of 500# and 1000# were applied at intervals up to calculated working load for fibre stress of 16000#. The deflections were taken at the center and one third point for each loading. The deflections were measured at the center by an Olsen deflectometer and at the third point by a Reihle deflectometer. Deflections at the third point were taken merely as a check on center deflections and the center deflections were used in plotting all curves.

The beams were first well cleaned with wire brushes and then framed in wooden boxing and these forms were

filled with concrete.

The concrete used was made of Chicago A.A. cement, sand and crushed rock, gravel or cinder in proportion of one : two : five. This aggregate was mixed with enough water to produce medium concrete.

The rock was crushed to pass through a 1" ring.

The gravel was clean and specified to pass through an 1½" ring.

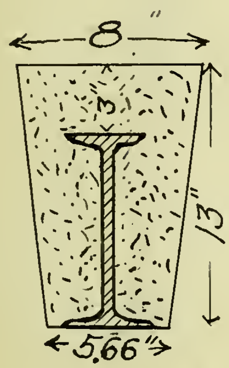
The cinders were clean and were obtained from the University.

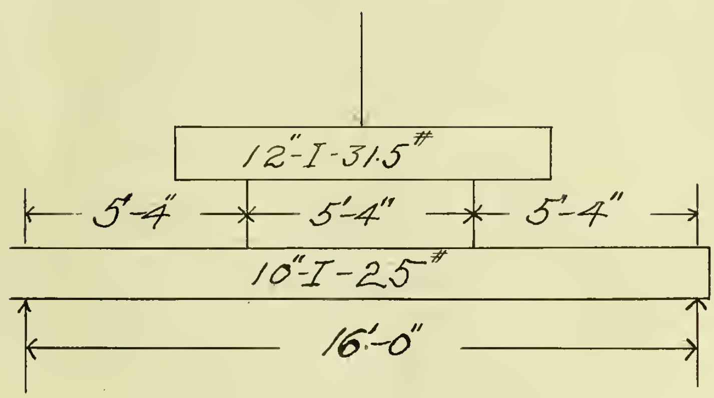
The sand was sharp and clean.

The cement was of Chicago A.A. brand. Neat briquettes gave at age of seven days an average strength of 668# per square inch; at age of 28 days 756# per sq. inch.

Test of Beam No. I

This beam was a 10"-25# I, 16'-6" long. span of 16'-0". The loads were applied at the third points 5'-4" from each end. Deflections were taken at center and third points and values at center were used in plotting for comparison with the concreted beam.

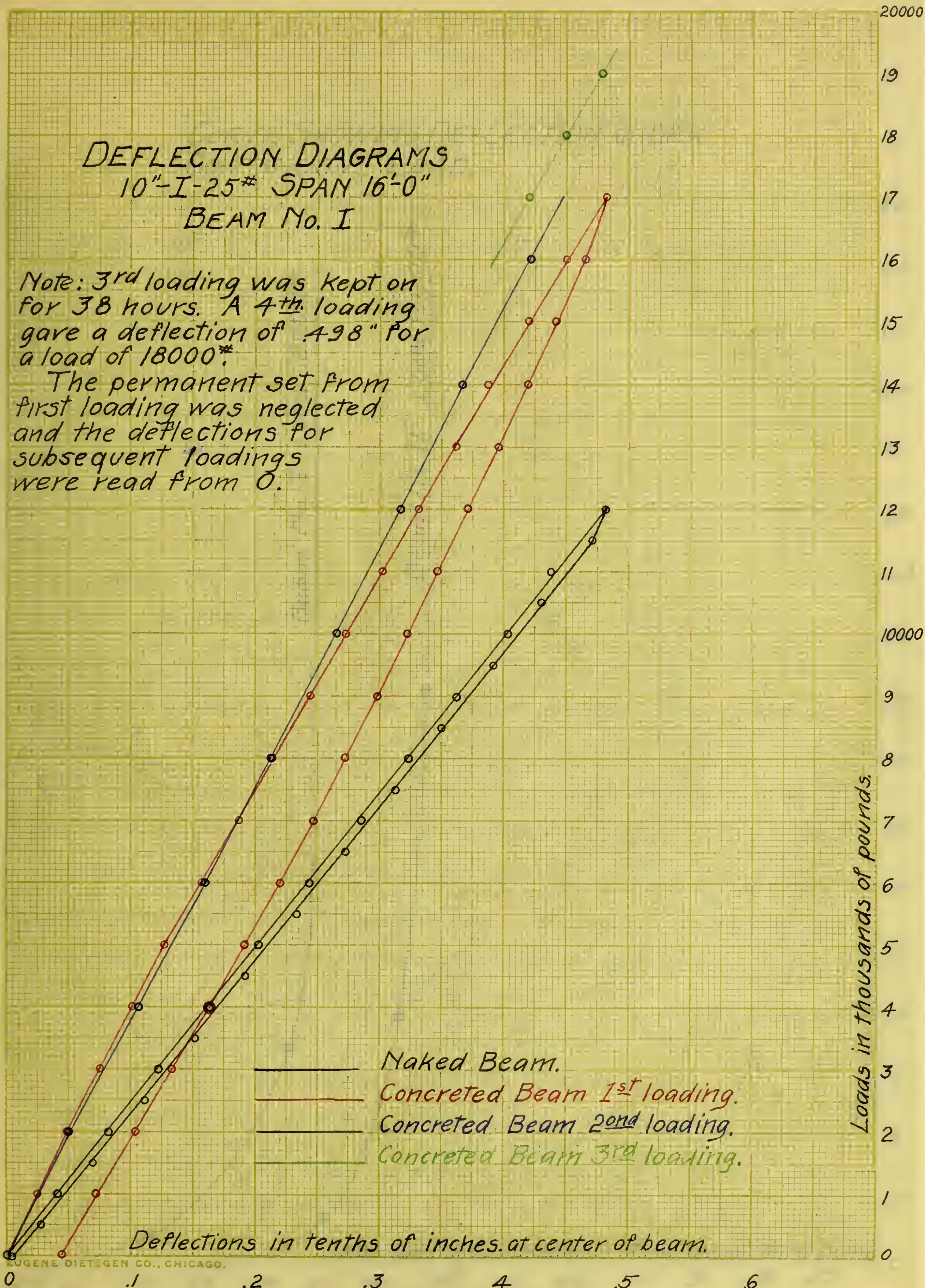


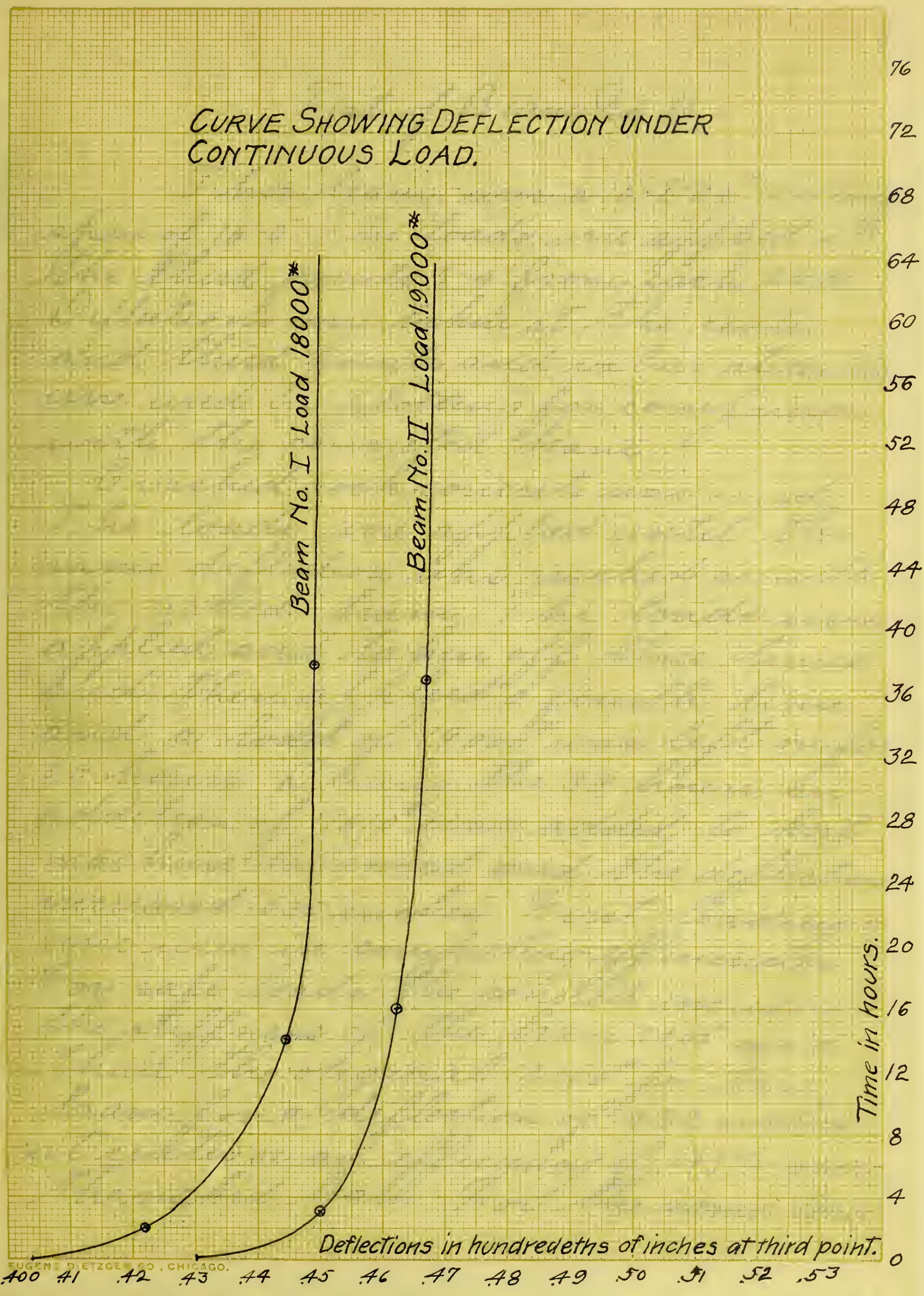


Crushed rock concrete was used. The loads were applied until the same deflections were reached as with the naked beam. The loads were applied and taken off twice and then applied a third time and a load of 18000# was kept on for 38 hours. During the 38 hours an addition of 1880# was added to keep the machine balanced and the deflection increased .045 inches. This additional load was applied at intervals of 2 hours,

14 hours and 37 hours from time test was started. By plotting a curve with number of hours as ordinates and deflections as abscissae one is led to believe that the final deflection has almost been reached at the end of 38 hours. When the load was taken off a permanent set of .025 inches was observed. When the third load was removed a fourth was applied. For safe loads the concrete increased the stiffness of the beam 5000# more than original 12000# for bare beam for a deflection of .48 in. at center or an efficiency of 141.7% over the naked beam

For the same load the concreted beam deflected 32% less than the naked beam.


DEFLECTION DIAGRAMS
10"-I-25# SPAN 16'-0"
BEAM No. I
Note: 3rd loading was kept on for 38 hours. A 4th loading gave a deflection of .498" for a load of 18000#.
The permanent set from first loading was neglected and the deflections for subsequent loadings were read from 0.
Naked Beam.
Concreted Beam 1st loading.
Concreted Beam 2ond loading.
Concreted Beam 3rd loading.
Deflections in tenths of inches. at center of beam.
Loads in thousands of pounds.
20000
19
18
17
16
15
14
13
12
11
10000
9
8
7
6
5
4
3
2
1
0
0
.1
.2
.3
.4
.5
.6
EUGENE DIETZGEN CO., CHICAGO.



CURVE SHOWING DEFLECTION UNDER CONTINUOUS LOAD.
Beam No. I Load 18000*
Beam No. II Load 19000*
Time in hours.
Deflections in hundredeths of inches at third point.
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
.400
.41
.42
.43
.44
.45
.46
.47
.48
.49
.50
.51
.52
.53
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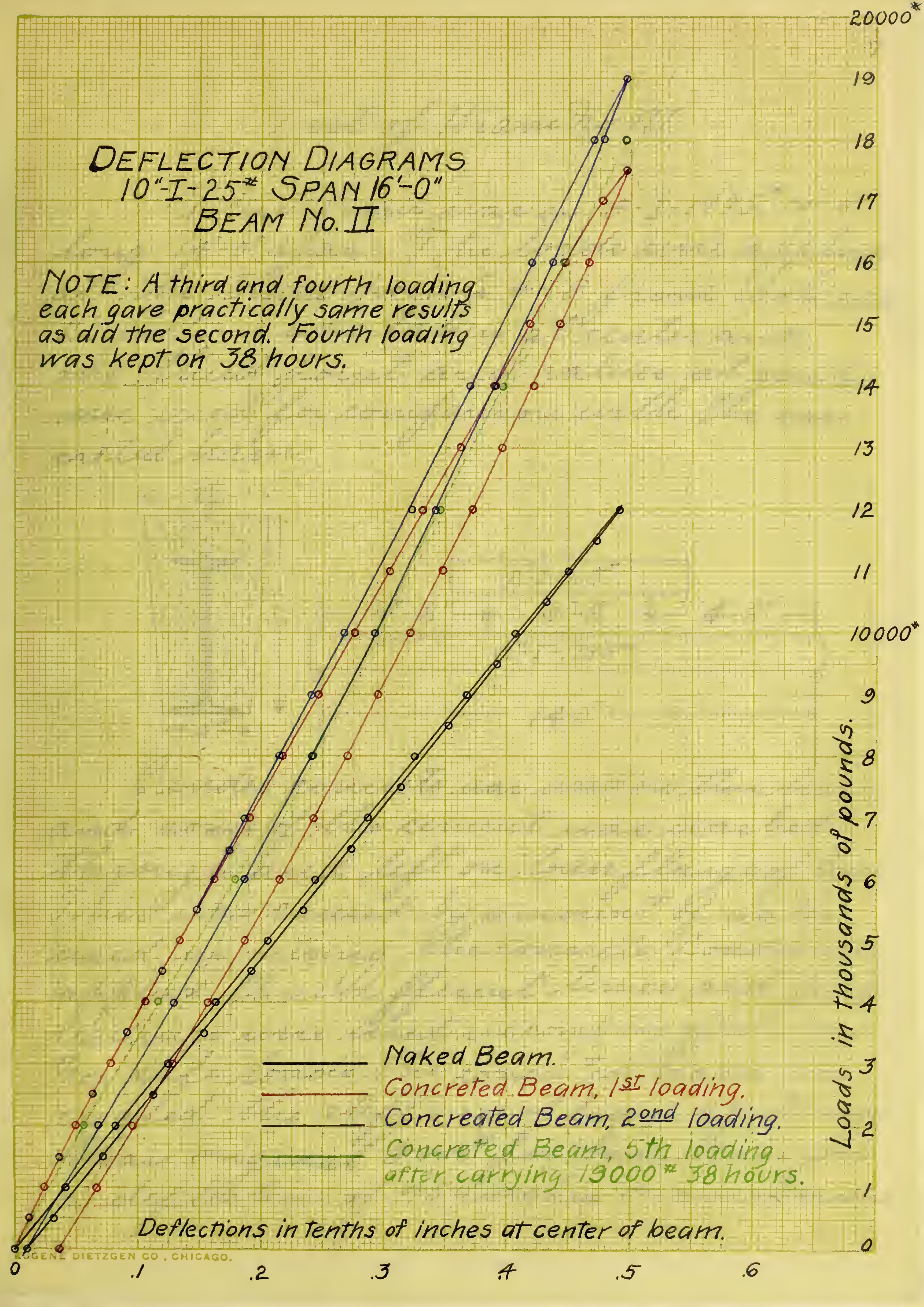
Test of Beam No. II

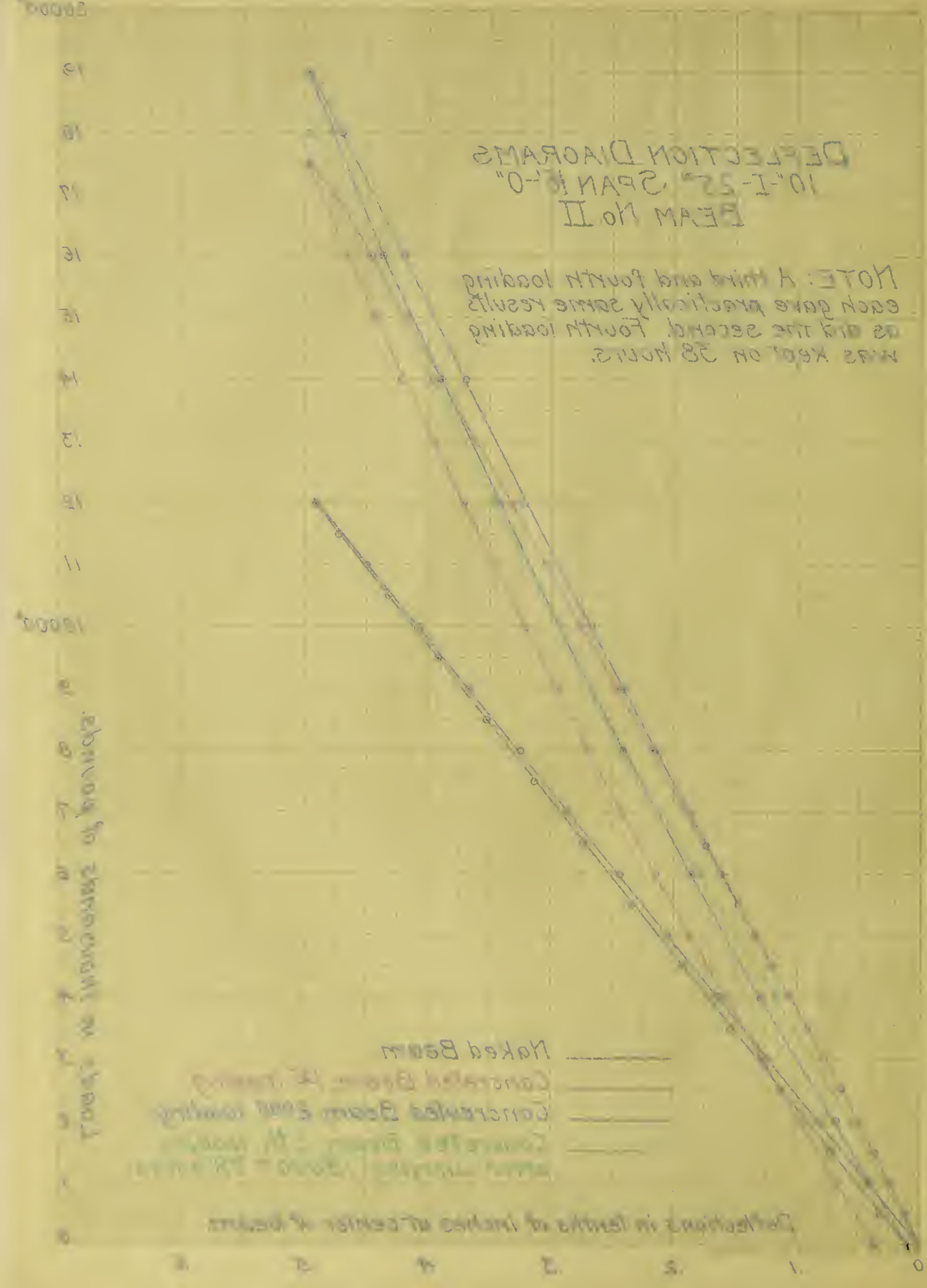
This beam was a 10"-I-25,# 16'-6" long span of 16'-0" The loads were applied at the third points, 5'-4" from each end. Deflections were taken at the center and third points and values at center were used in plotting for comparison with the concreted beam.

Crushed rock concrete was used. The loads were applied until the same deflection was reached as with the naked beam. The loads were applied and taken off three times and then applied a fourth time and a load of 19000# was left on for 38 hours. During the 38 hours an addition of 1610# was added to keep machine balanced and the deflection increased .035 inches. First loadings were used in computing efficiencies. For safe loads the concrete increased the stiffness of the beam 5400# more than the original 12000# for bare beam for a deflection of .492 inches at center or an efficiency of 145% over the naked beam. For the same load

the concreted beam deflected 33% less than the naked beam.

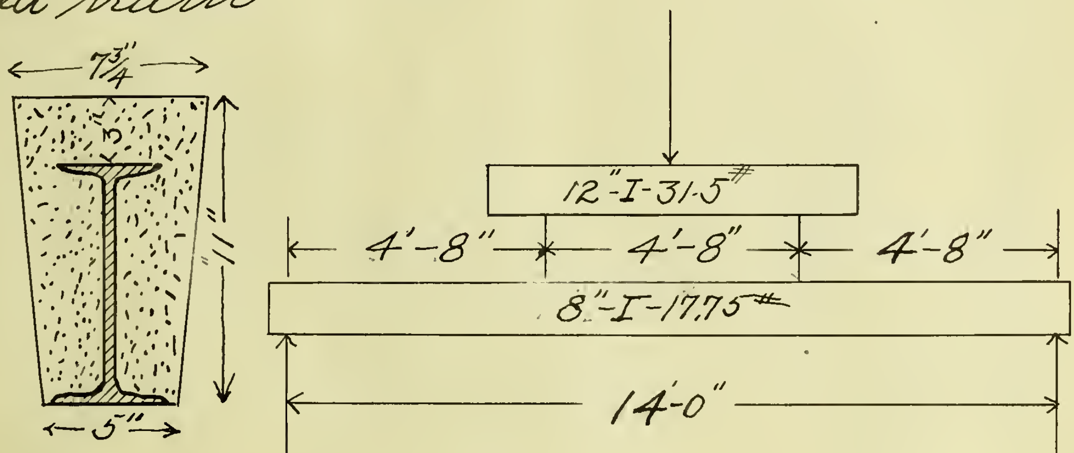
At the end of 38 hours load was taken off and a permanent set of .005 inches was observed. Two more loads of 18000# each were then applied


DEFLECTION DIAGRAMS
10"-I-25* SPAN 16'-0"
BEAM No. II
NOTE: A third and fourth loading each gave practically same results as did the second. Fourth loading was kept on 38 hours.
Naked Beam.
Concreted Beam, 1st loading.
Concreated Beam, 2ond loading.
Concreted Beam, 5th loading after carrying 19000* 38 hours.
Deflections in tenths of inches at center of beam.
Loads in thousands of pounds.
20000*
19
18
17
16
15
14
13
12
11
10000*
9
8
7
6
5
4
3
2
1
0
0
.1
.2
.3
.4
.5
.6
EUGENE DIETZGEN CO., CHICAGO.


DEFLECTION DIAGRAMS
10"-I-25# SPAN 15'-0"
BEAM No II
NOTE: A third and fourth loading each gave practically same results as did the second. Fourth loading was kept on 38 hours.
Naked Beam
Concreted Beam 1st loading
Concreted Beam 2nd loading
Loads in thousands of pounds
Deflections in tenths of inches at center of beams
20000
19
18
17
16
15
14
13
12
11
10000
9
8
7
6
5
4
3
2
1
0
.6
.5
.4
.3
.2
.1
0

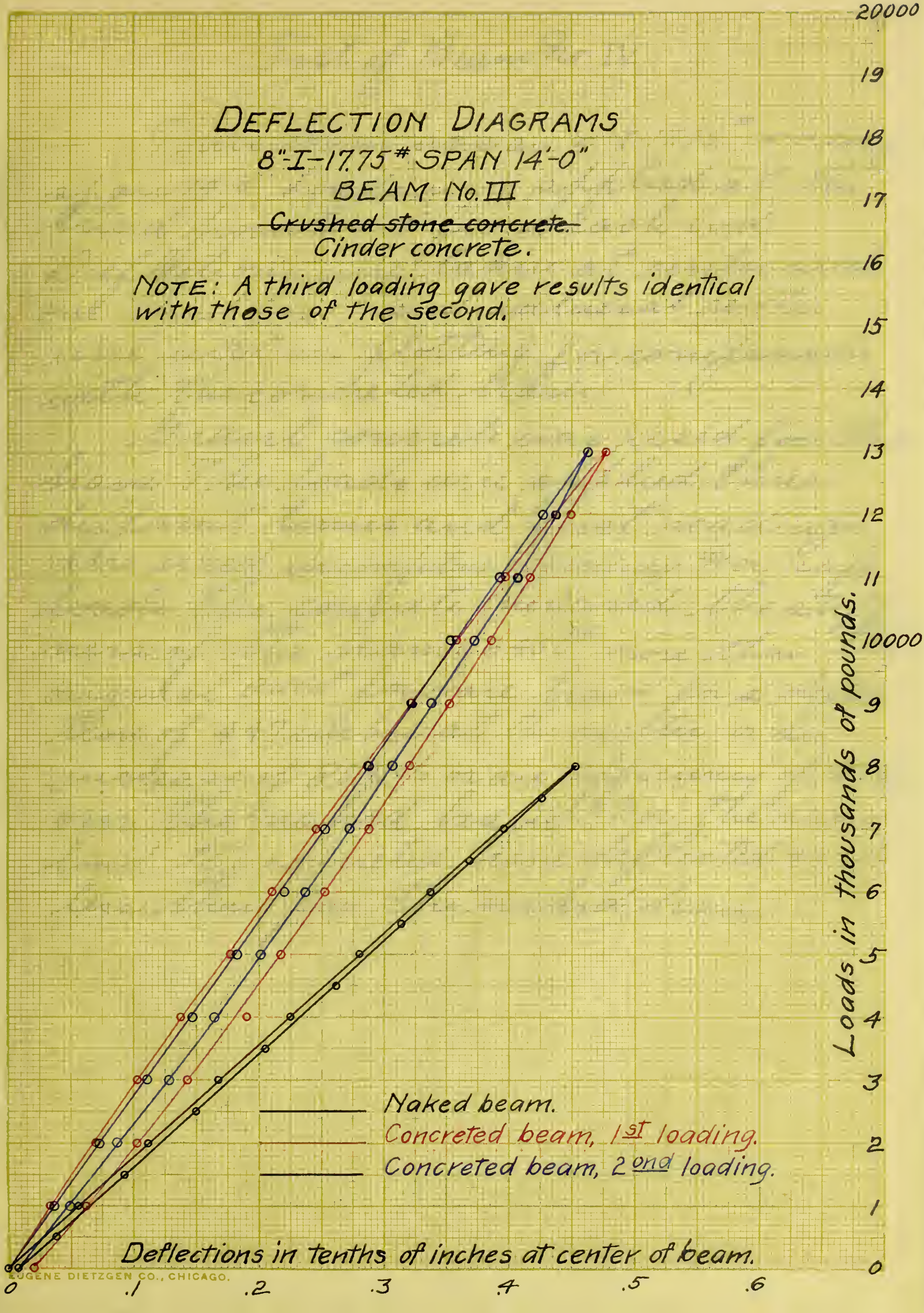
Test of Beam No. III.

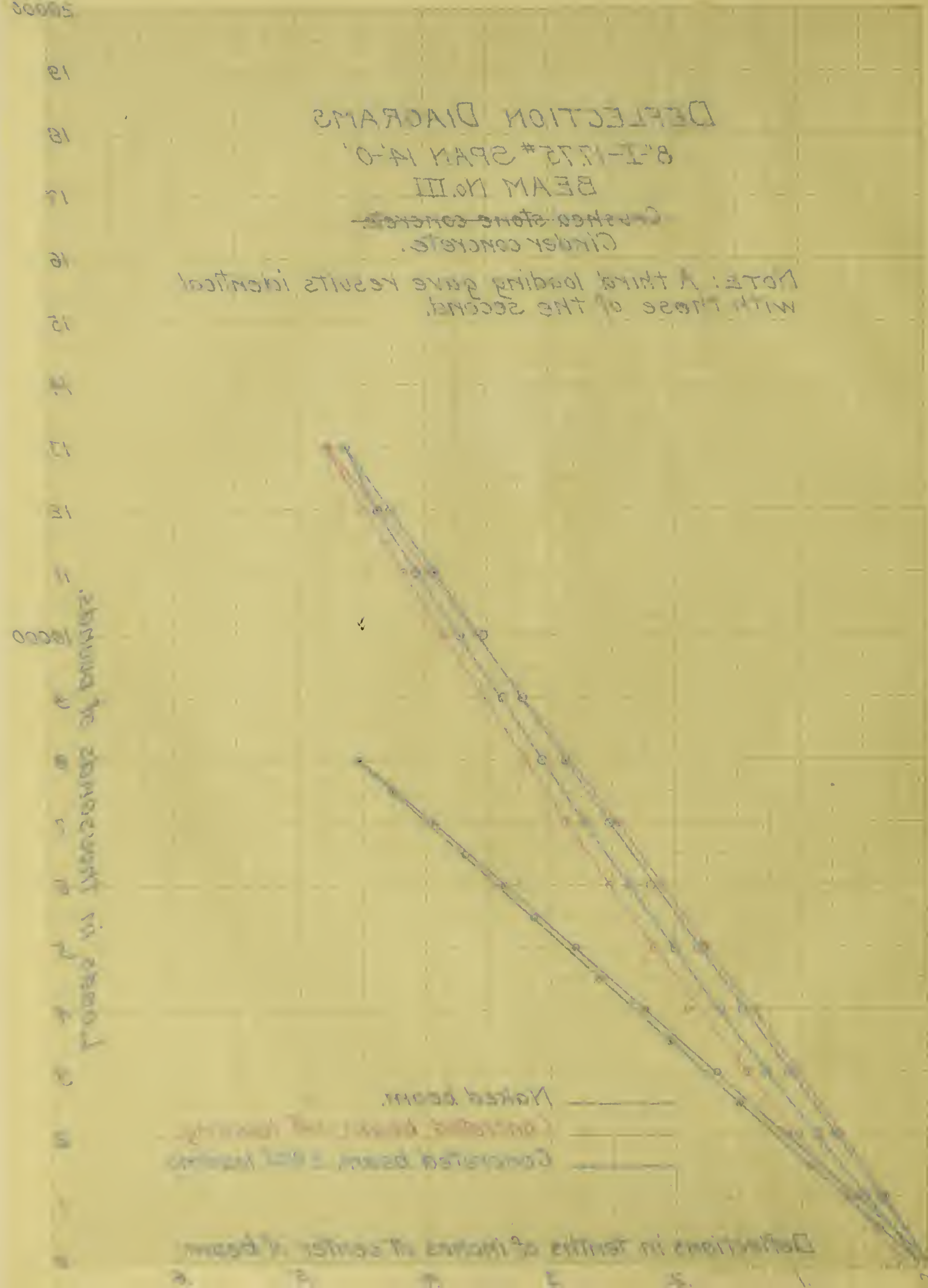
This beam was an 8"-I-17.75,# 14'-6" long, 14'-0" span. The loads were applied at the third points, 4'-8" from each end. Deflections were taken at center and one third point and values at center were used for comparison with the concreted beam.



Cinder concrete was used on this beam, and some of the cement was washed through and left on lower flange of beam. This was caused by amount of water used in mixing the concrete. Loads were applied three different times and first readings were used in computing efficiency. For safe loads the concreted beam increased the stiffness of beam 4400# more than original 8000# for bare beam for a deflection of .456 inches or an increase

of 55% or an efficiency of 155% over the naked beam. For the same load the beam deflected 37.5% less than the naked beam.

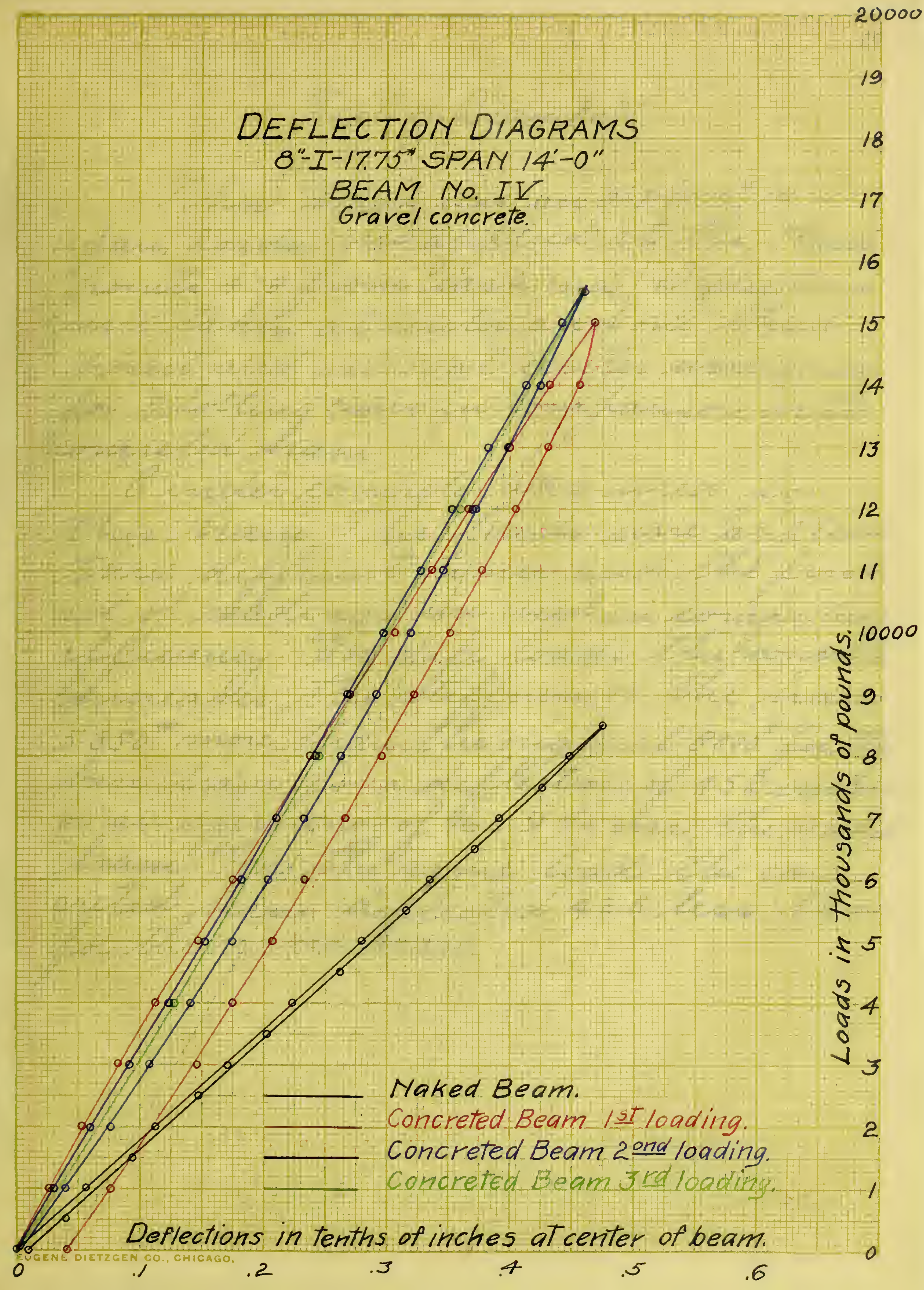

DEFLECTION DIAGRAMS
8"-I-17.75# SPAN 14'-0"
BEAM No. III
~~Crushed stone concrete.~~
Cinder concrete.
NOTE: A third loading gave results identical with those of the second.
Naked beam.
Concreted beam, 1st loading.
Concreted beam, 2ond loading.
Deflections in tenths of inches at center of beam.
Loads in thousands of pounds.
20000
19
18
17
16
15
14
13
12
11
10000
9
8
7
6
5
4
3
2
1
0
0
.1
.2
.3
.4
.5
.6
EUGENE DIETZGEN CO., CHICAGO.

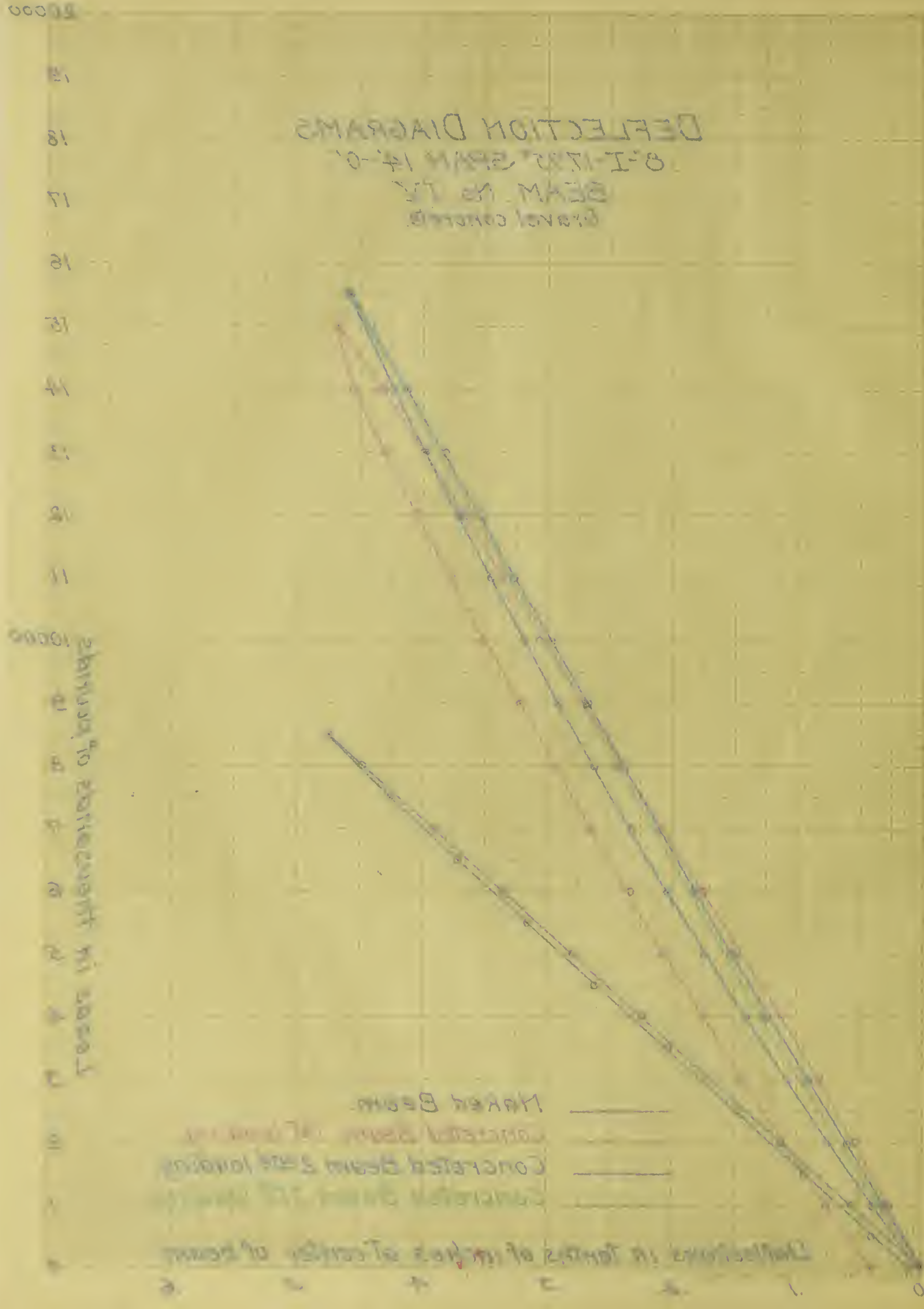

DEFLECTION DIAGRAMS
8"-I-17.75# SPAN 14'-0"
BEAM No. III
~~Crushed stone concrete.~~
Cinder concrete.
NOTE: A third loading gave results identical with those of the second.
Naked beam.
Concreted beam, 1st loading.
Concreted beam, 2nd loading.
Loads in thousands of pounds.
Deflections in tenths of inches at center of beam.
20000
10000

Test of Beam No. IV

This beam was an 8"-I-17.75#, 14'-6" long, span 14'-0". Loads were applied at the third points 4'-8" from each end. Deflections were taken at center and one third point and values at center were used in plotting for comparison with the concreted beam.

Gravel concrete was used for this beam. The loads were applied three different times and first readings were used in computing efficiency. For safe loads the concrete increased the stiffness of the beams 6450# more than the original 8000# for bare beam for a deflection of .447 inches at the center. or an increase of 80.6% or an efficiency of 180.6% over the naked beam. For the same load the concreted beam deflected 40.7% less than for the naked beam.

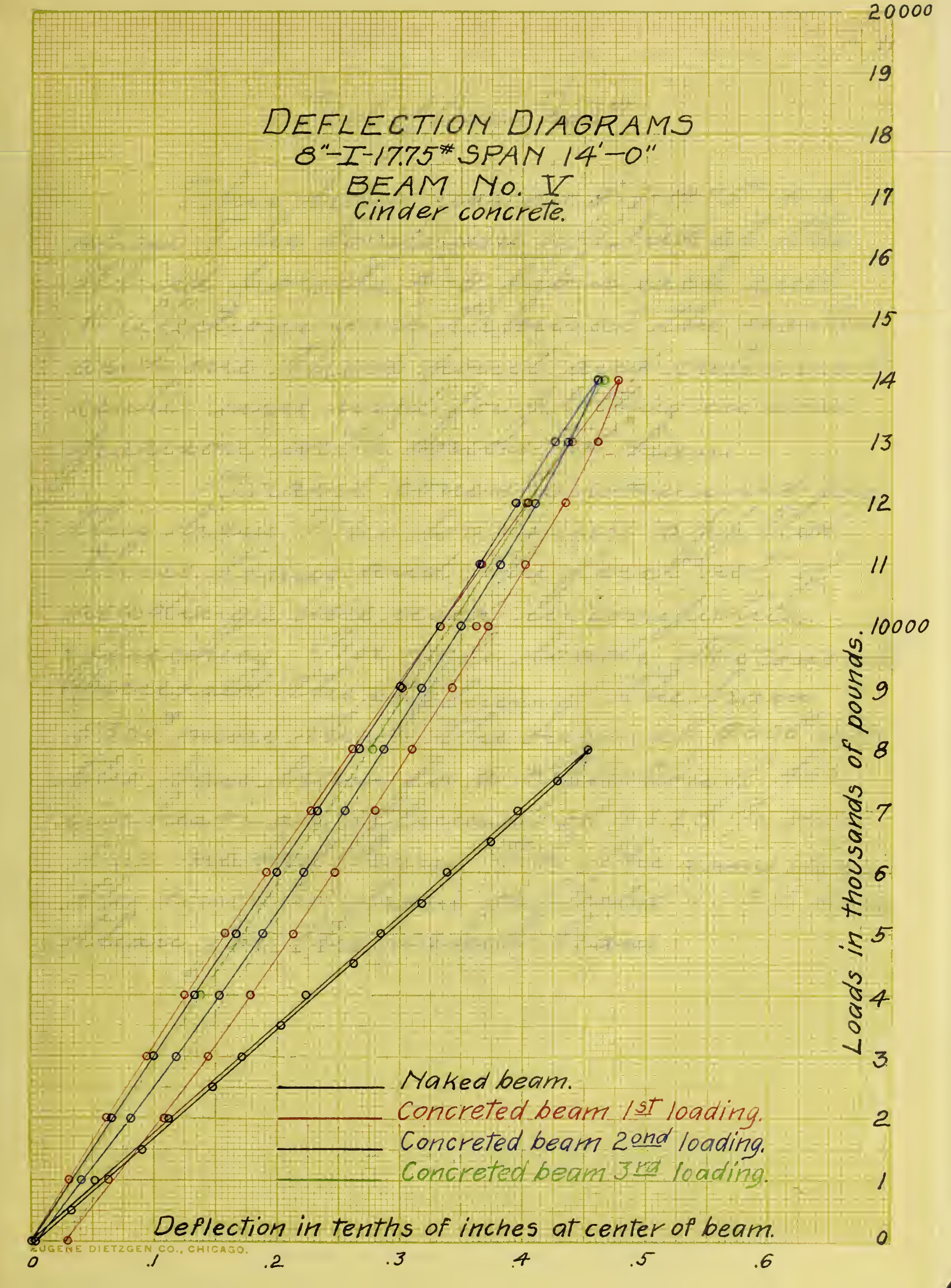

DEFLECTION DIAGRAMS
8"-I-17.75" SPAN 14'-0"
BEAM No. IV
Gravel concrete.
Naked Beam.
Concreted Beam 1st loading.
Concreted Beam 2ond loading.
Concreted Beam 3rd loading.
Deflections in tenths of inches at center of beam.
Loads in thousands of pounds.
20000
19
18
17
16
15
14
13
12
11
10000
9
8
7
6
5
4
3
2
1
0
0
.1
.2
.3
.4
.5
.6
EUGENE DIETZGEN CO., CHICAGO.

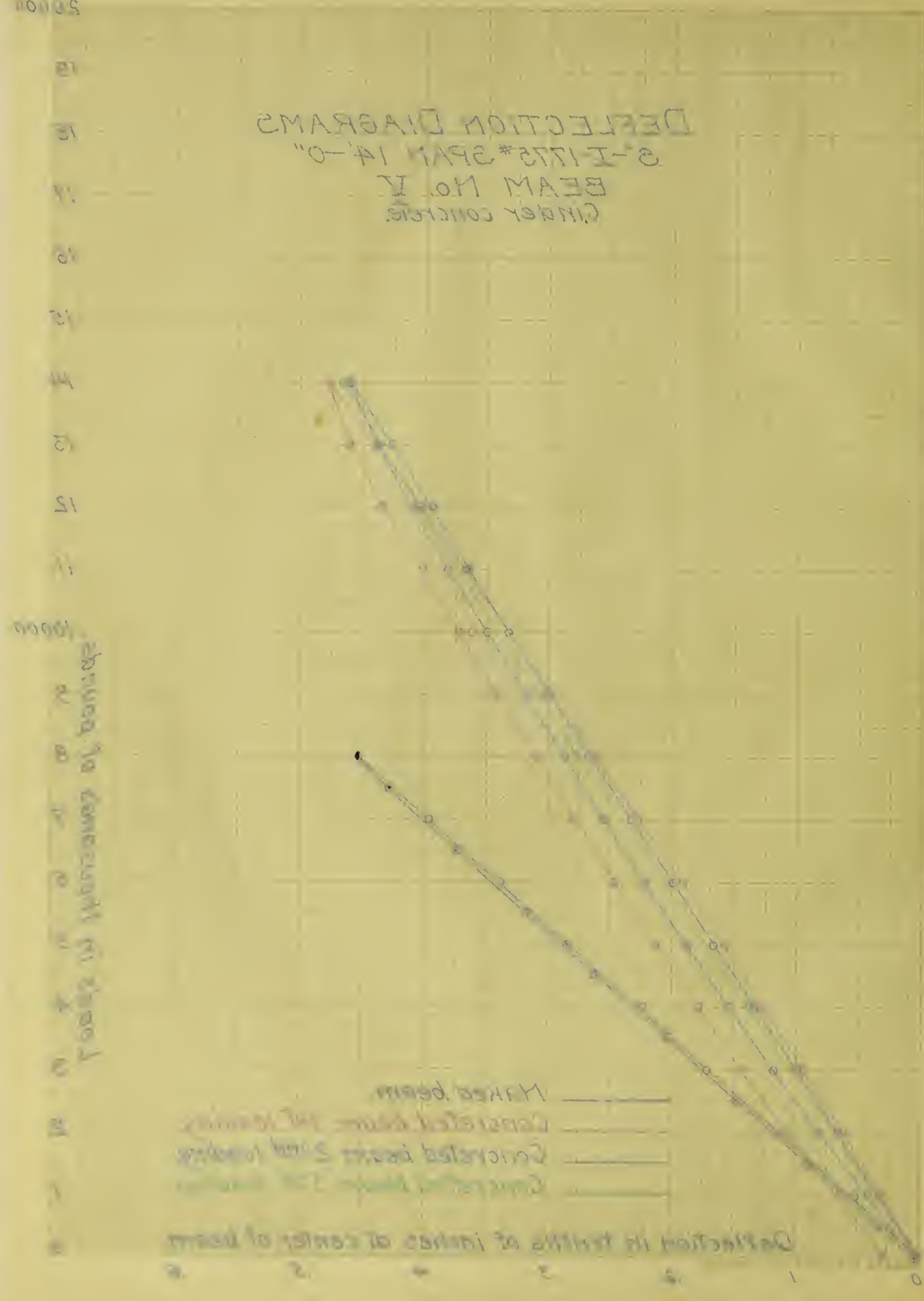

DEFLECTION DIAGRAMS
SPAN 14'-0"
Gravel concrete
Naked Beam
Concreted Beam 2nd loading
20000
10000
0
.1
.2
.3
.4
.5
.6

Test of Beam No. V.

This beam was an 8"-I-17.75#, 14'-0" span, Loads were applied at the third points 4'-8" from each end. Deflections were taken at center and one third point and values at center were used for plotting curve in comparison with concreted beam.

Cinder concrete was used for this beam. The loads were applied three different times and the first set of readings were used in computing efficiency. For safe loads the concrete increases the stiffness of the beam 5350# more than the original 8000# for the bare beam for a deflection of .452 inches or an efficiency of 166.9% over the naked beam. For the same load the concreted beam deflected 42.5 less than for the naked beam.

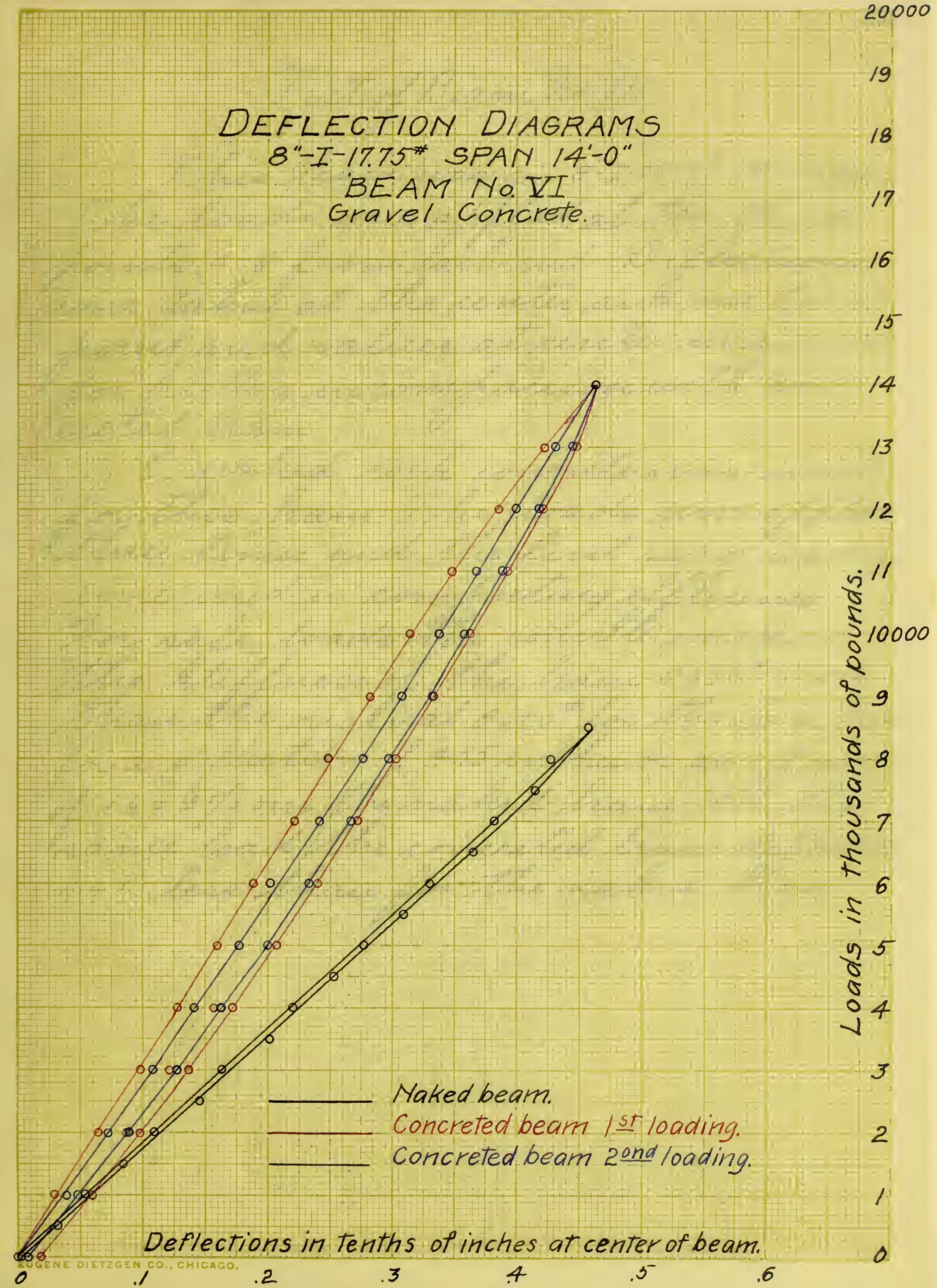

DEFLECTION DIAGRAMS
8"-I-17.75# SPAN 14'-0"
BEAM No. V
Cinder concrete.
Naked beam.
Concreted beam 1st loading.
Concreted beam 2ond loading.
Concreted beam 3rd loading.
Deflection in tenths of inches at center of beam.
Loads in thousands of pounds.
20000
19
18
17
16
15
14
13
12
11
10000
9
8
7
6
5
4
3
2
1
0
0
.1
.2
.3
.4
.5
.6
EUGENE DIETZGEN CO., CHICAGO.


DEFLECTION DIAGRAMS
5"-I-17.75# SPAN 14'-0"
BEAM No. V
Cinder concrete
Naked beam
Corrected above 2nd loading
Deflection in tenths of inches at center of beam
Load in thousands of pounds

Test of Beam No. VI.

This beam was an 8"-I-17.75# 14'-0" span. The loads were applied at the third points, 4'-8" from each end. Deflections were taken at the center and one third point and values at center were used for plotting in comparison with concreted beam.

Gravel concrete was used for this beam. The loads were applied three times and the first set of readings were used in computing efficiency. For safe loads the concrete increased the stiffness of the beam 5300# more than the original 8000# for the bare beam for a deflection of .465 inches or an efficiency of 166.25 % over the naked beam. For the same load the concreted beam deflected 46.8% less than for the naked beam.


DEFLECTION DIAGRAMS
8"-I-17.75# SPAN 14'-0"
BEAM No. VI
Gravel Concrete.
Naked beam.
Concreted beam 1st loading.
Concreted beam 2ond loading.
Deflections in tenths of inches at center of beam.
Loads in thousands of pounds.
20000
19
18
17
16
15
14
13
12
11
10000
9
8
7
6
5
4
3
2
1
0
0
.1
.2
.3
.4
.5
.6
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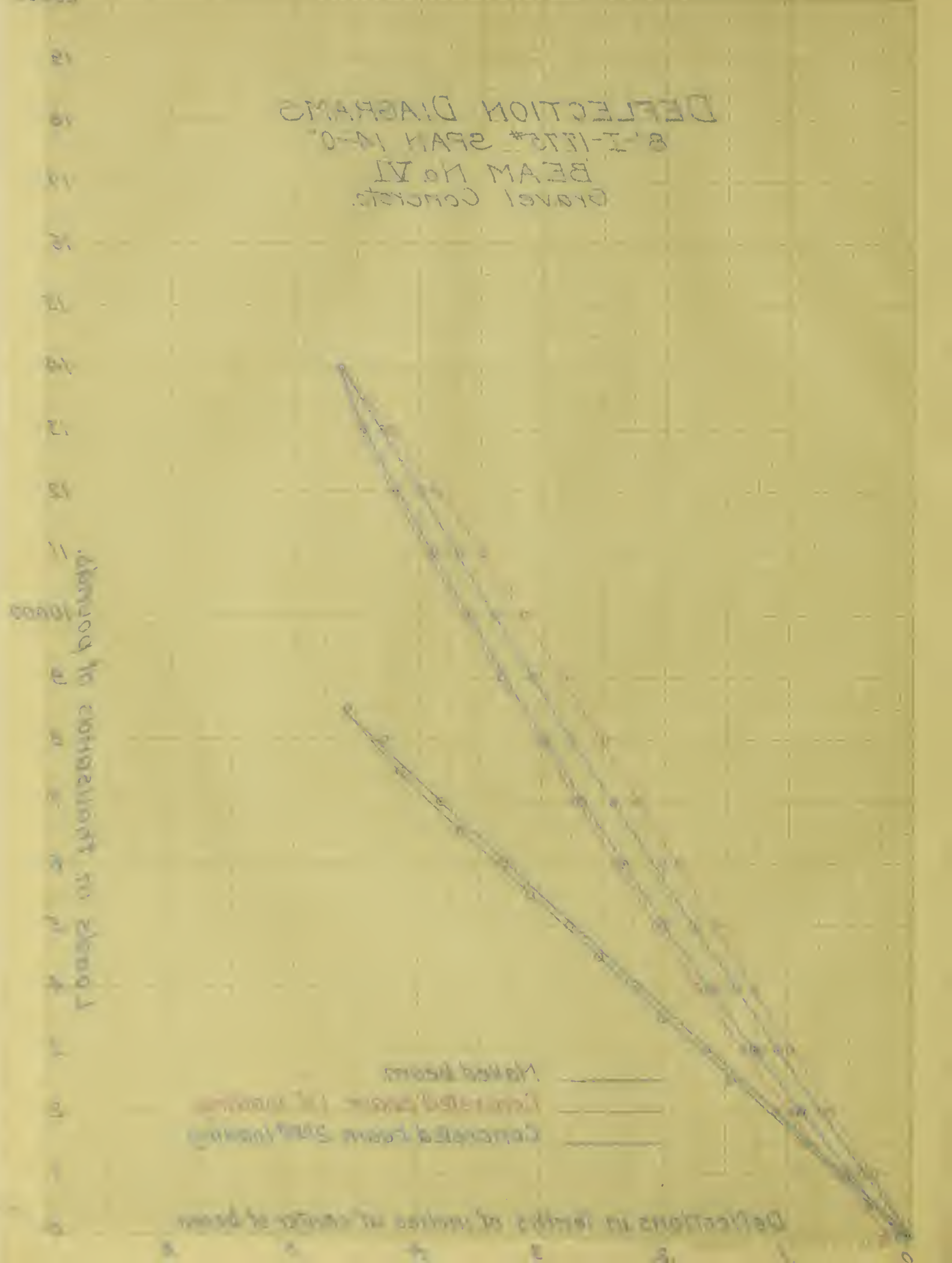
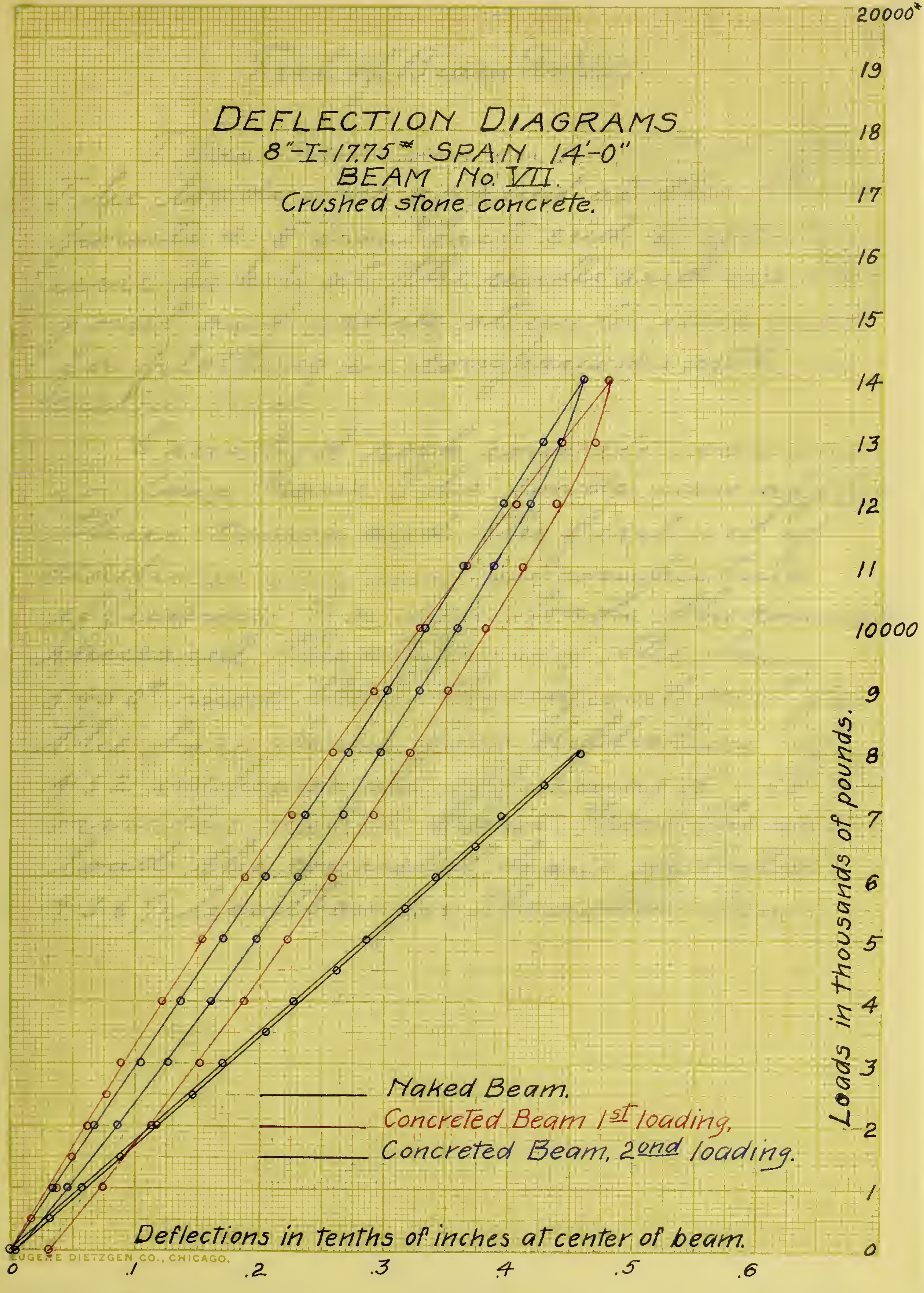


DEFLECTION DIAGRAMS
8"-I-17.75# SPAN 14'-0"
BEAM No VI
Gravel Concrete.
Naked beam
Concreted beam: 1st loading
Concreted beam 2nd loading
Deflections in tenths of inches at center of beam

Test of Beam No. VII

This beam was an 8"-I-17.75#, 14'-0" span. The loads were applied at the third points, 4'-8" from each end. Deflections were taken at the center and one third point and values at center were used for plotting in comparison with concreted beam.

Crushed rock concrete was used for this beam. The loads were applied three times and the first set of readings were used in computing efficiency. For safe loads the concrete increased the stiffness of the beam 5350# more than the original 8000# for the bare beam for a deflection of .455 inches or an efficiency of 166.9% over the naked beam. For the same load the concreted beam deflected 44% less than for the naked beam.



DEFLECTION DIAGRAMS
8"-I-17.75# SPAN 14'-0"
BEAM No. VII.
Crushed stone concrete.
Naked Beam.
Concreted Beam 1st loading.
Concreted Beam, 2ond loading.
Deflections in tenths of inches at center of beam.
Loads in thousands of pounds.
20000#
19
18
17
16
15
14
13
12
11
10000
9
8
7
6
5
4
3
2
1
0
0
.1
.2
.3
.4
.5
.6
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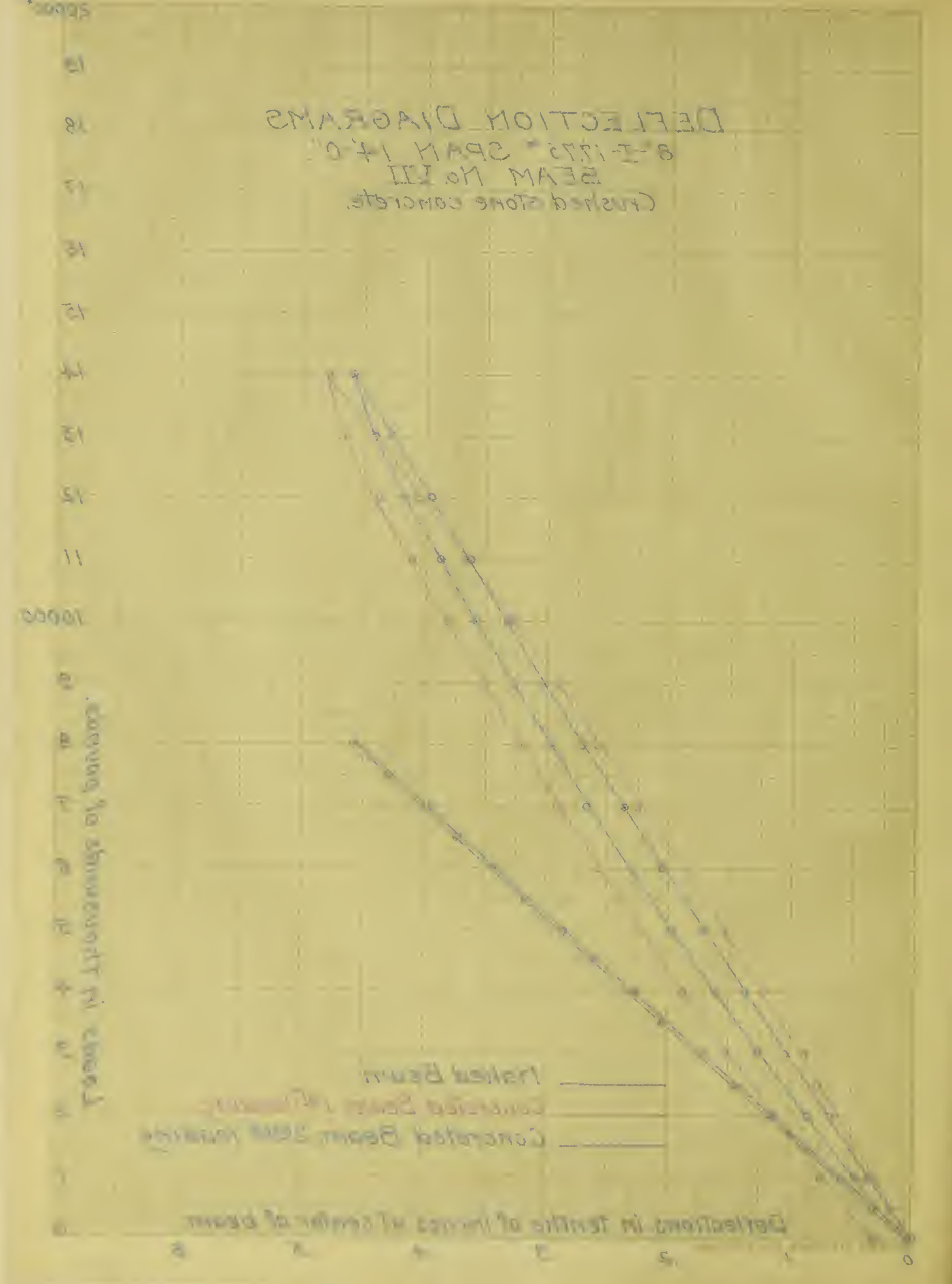
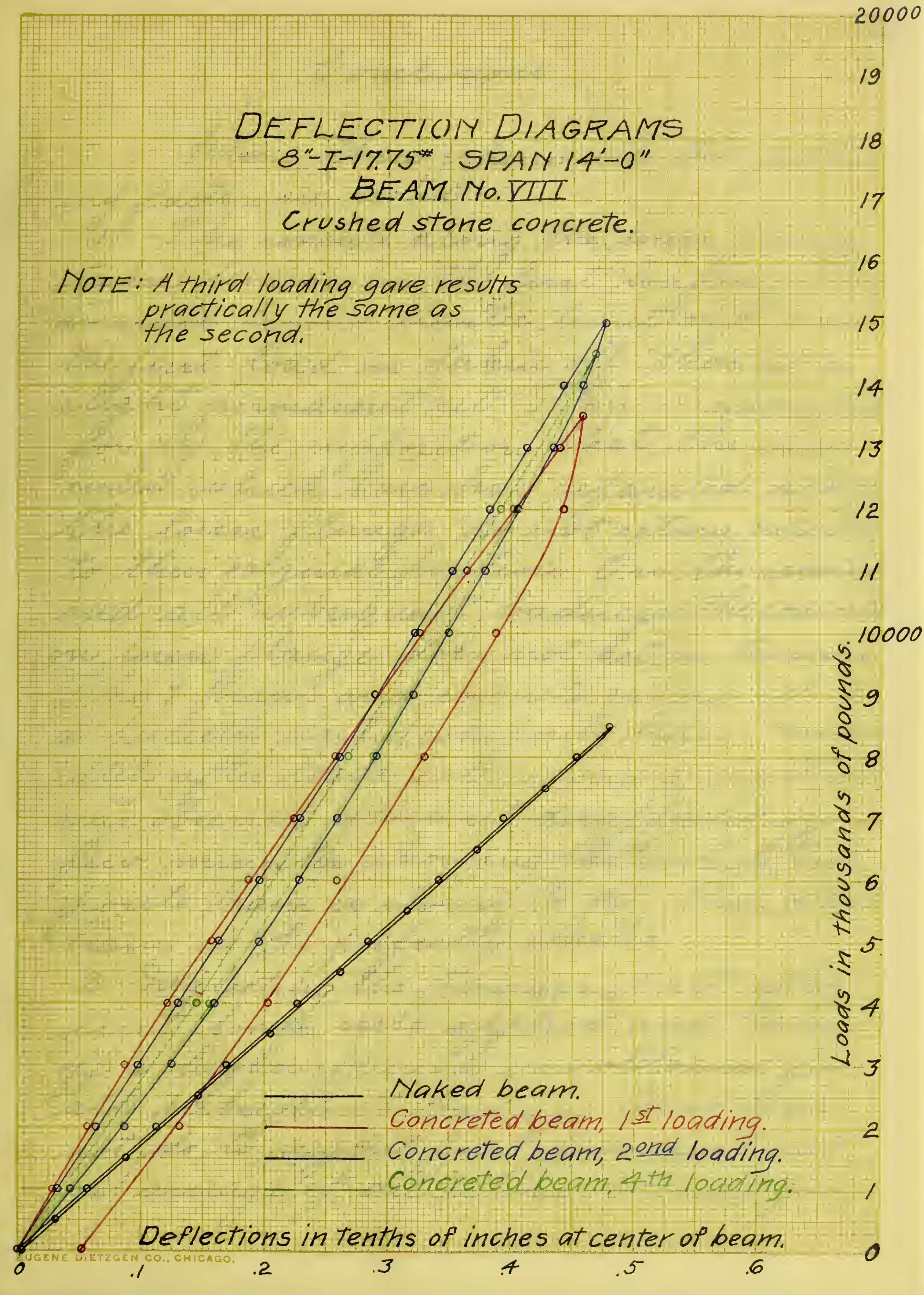

DEFLECTION DIAGRAMS
8"-I-17.75# SPAN 14'-0"
BEAM No. XII
(Crushed stone concrete.)
Naked Beam
Load in thousands of pounds.
Deflections in tenths of inches of center of beam.

Test of Beam No. VIII

This beam was an 8"-17.75#-I, 14'-0 span. The loads were applied at the third points, 4'-8" from each end. Deflections were taken at the center and one third point and values at center were used for plotting in comparison with concreted beam.

Crushed rock concrete was used for this beam. The loads were applied three times and the first set of readings were used in computing efficiency. For safe loads the concrete increased the stiffness of the beam 5450# more than the original 8000# for the bare beam for a deflection of .452 inches or an efficiency of 168% over the naked beam. For the same load the concreted beam deflected 43.6% less than for the naked beam.


DEFLECTION DIAGRAMS
8"-I-17.75# SPAN 14'-0"
BEAM No. VIII
Crushed stone concrete.
NOTE: A third loading gave results practically the same as the second.
Naked beam.
Concreted beam, 1st loading.
Concreted beam, 2nd loading.
Concreted beam, 4th loading.
Deflections in tenths of inches at center of beam.
Loads in thousands of pounds.
20000
19
18
17
16
15
14
13
12
11
10000
9
8
7
6
5
4
3
2
1
0
0
.1
.2
.3
.4
.5
.6
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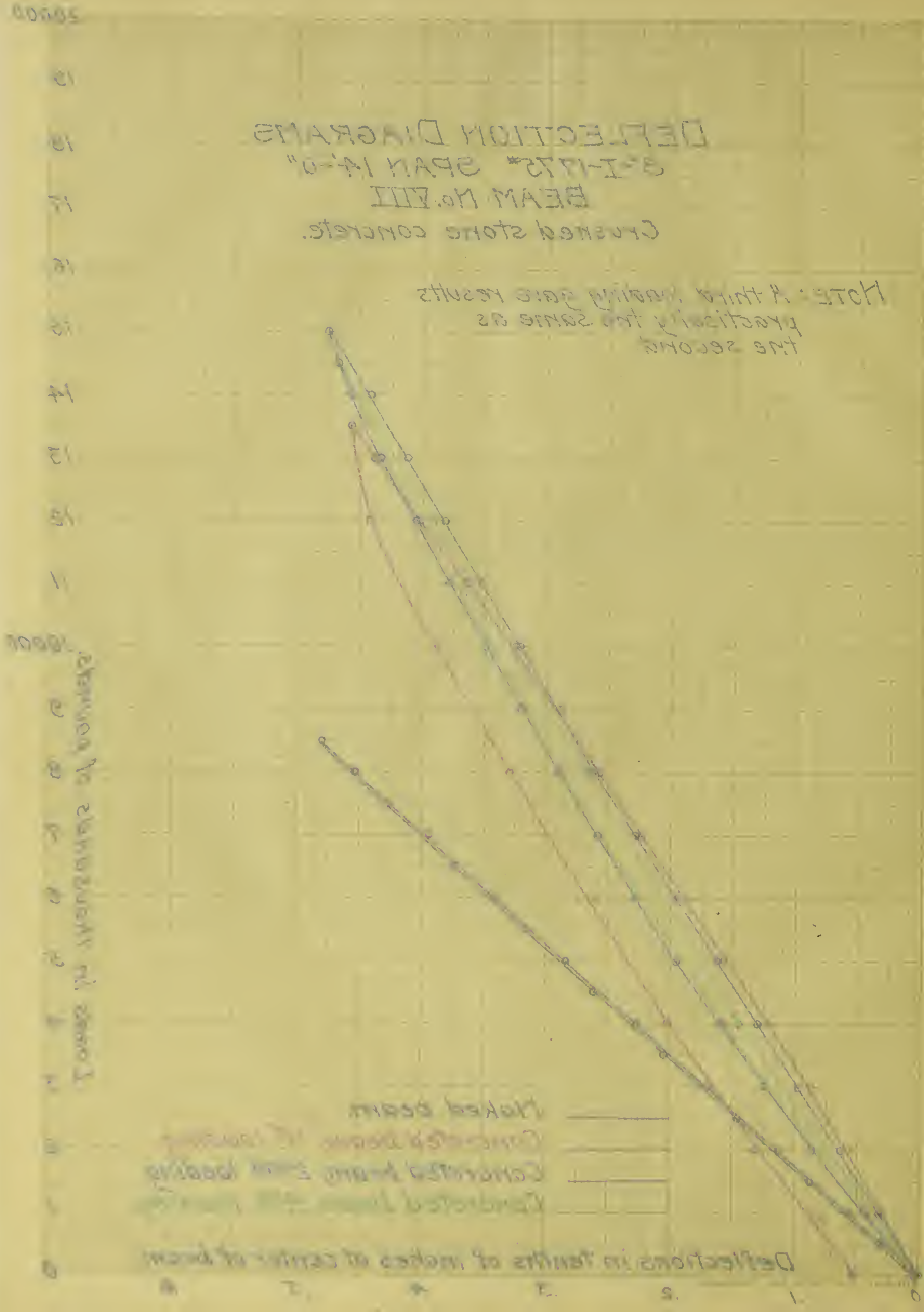
DEFLECTION DIAGRAMS
3"-I-19.75# SPAN 14'-0"
BEAM No. VIII
Crushed stone concrete.
NOTE: A third loading gave results practically the same as the second.
Naked beam
Concreted beam, 1st loading
Concreted beam, 2nd loading
Deflections in tenths of inches at center of beam
Loads in thousands of pounds
20000
10000

Conclusions

From these experiments the following facts were noted:-

1. The concrete along the lower flange takes tension on the first loading until strained beyond elastic limit(?) and when the first load is taken off there is a slight permanent set. This is accounted for by the supposition that the molecules, which have been separated along the lower flange, do not return entirely to their original position. On the second and all subsequent loadings the concrete on lower flange does not act in tension. The I beam and concrete casing act as a perfectly elastic composite beam. Immediately after loads were removed a slight set was observed which set disappeared in a few minutes showing that while the composite beam is slower to act than steel beam yet it is perfectly elastic.

2. Neglecting the permanent set after first loads were applied and taken off a higher efficiency was obtained for all subsequent loadings. As it does not do to neglect first permanent set an average of deflections obtained from

first loadings was taken in determining efficiency. With the 8" beams for crushed rock concrete an efficiency of 167.5% was obtained. The gravel concrete gave an efficiency of 178.4%. For cinder concrete the efficiency was 161%.

With 10" beams and crushed rock concrete an efficiency of 143% was obtained for loads applied and immediately taken off. For loads left on 38 hours the efficiency was 132% showing the efficiency is less for continuous loads. On this account previous efficiencies should be reduced 10% for practical work

A greater efficiency is obtained for the 8" beams than for the 10" beams owing to the fact that the span is shorter and that the amount of concrete above the upper flange is greater in proportion to the depth of the beam.