

LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING AND MECHANICS
BETHLEHEM, PA.

ADDRESS REPLY TO:
FRITZ ENGINEERING LABORATORY

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HYDRAULICS LAB. EXT. 279

25 October 1951

File No. 205.15

TO: MEMBERS OF LEHIGH PROJECT SUBCOMMITTEE

PROGRESS REPORT N

Enclosed follows a short summary of a paper by Prof., Dr. Ing. Maier-Leibnitz, "CONTRIBUTION TO THE PROBLEM OF ULTIMATE CARRYING CAPACITY OF SIMPLE AND CONTINUOUS BEAMS OF STRUCTURAL STEEL AND TIMBER", which appeared in German in Die Bautechnik, Heft 1, 6. Jan., 1927.*

We believe this abstract will be of interest to you. The paper is one of the first attempts toward pointing out the reserve carrying capacity of ductile steel members, due to redistribution of moments through the development of plastic hinges.

The approach to the problem is different from that governing our current investigation. The prime purpose of the summarized paper was to defeat the arguments against continuous beams, at that time thought to require perfectly rigid supports. The discussors generalized the results to justify a wider use of statically indeterminate structures as a whole, an effect to which the paper no doubt contributed.

The concepts of Z_p , plastic modulus of a cross-section, and M_p , the plastic hinge moment, were introduced by Grüning in a paper "Ultimate Carrying Capacity of Statically Indeterminate Steel Trusses", October 1926. This was mentioned by Grüning in discussing Maier-Leibnitz' paper.

Sincerely yours,

Knud-Endre Knudsen
Asst. Prof. of C. E.

Lynn S. Beedle
Assistant to the Director

LSB:KEK:fs

* The original paper is available on loan from Fritz Laboratory.

PROGRESS REPORT NCONTRIBUTION TO THE PROBLEM OF
ULTIMATE CARRYING CAPACITY OF
SIMPLE AND CONTINUOUS BEAMS OF
STRUCTURAL STEEL AND OF TIMBER

By Prof., Dr.Ing. Maier-Leitnitz, Stuttgart

Summary translated from article in
Die Bautechnik, Heft 1, 6. Januar 1927 ← ?
Vol. 6, Feb. 1928

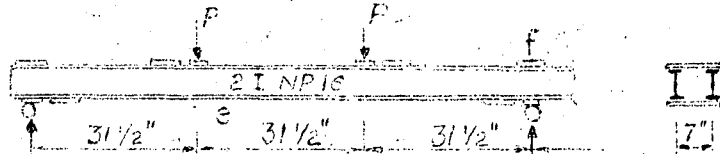
INTRODUCTION:

The cross-section of simple and continuous beams are usually kept constant all along the length of the beam. This cross-section is determined by the section, usually at an interior support, which obtains the highest bending moment according to the elastic theory. The moment distribution in a continuous beam will thereby vary greatly with possible vertical movements of any one support, which has widely caused a feeling against the application of continuously designed beams, especially among building authorities. In one particular case, this feeling was so strong that a structure, designed as continuous, was required constructed as simple beams, using the same members as selected on basis of the continuous design.

To throw light upon the question whether the calculated maximum moments at supports have any influence at all on the ultimate carrying capacity of continuous beams, and to investigate

the effect of downward deflections of supports, and finally to show, at least in some special cases, how the reserve capacity inherent in the building material may be counted on (as it has been up to now simply by the intuition of designers), a series of tests were performed. Sponsors were the Scientific Research Society of Württemberg, through the Materials Testing Laboratory of the Technical Institute of Stuttgart (Director: Professor O. Graf).

SPECIMENS: (Only the part of the paper on steel beams is treated here.)

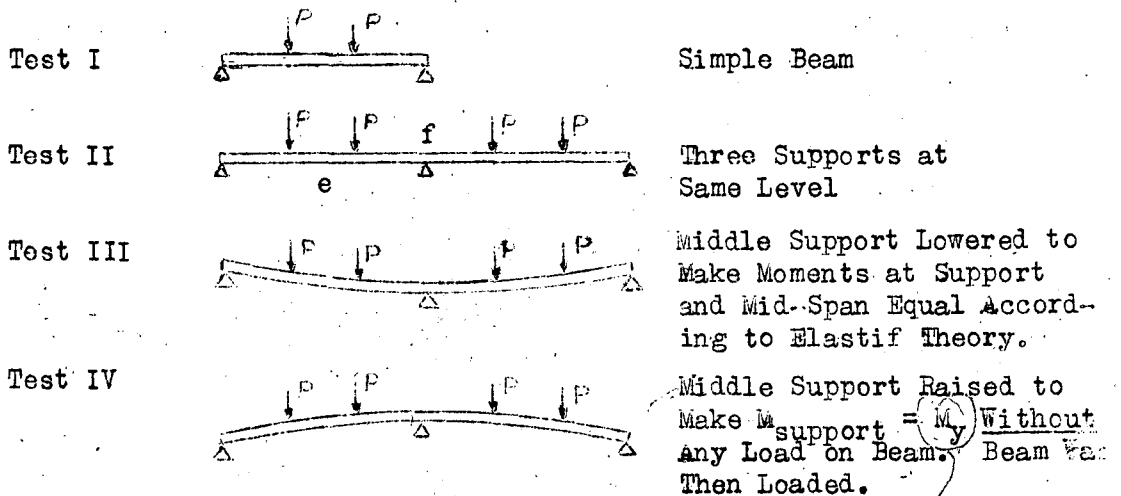


Section Properties Approximately Corresponding to

2 NP 16	2-6I 12.5
$A=2 \times 22.8 \text{ cm}^2 (2 \times 3.52 \text{ in}^2)$	$2 \times 3.61 \text{ in}^2$
$S=2 \times 117 \text{ cm}^3 (2 \times 7.13 \text{ in}^3)$	$2 \times 8.8 \text{ in}^2$

(One test with one I-beam gave lateral buckling.)

TEST CONDITIONS: (See Fig. 1, p. 12)



M_w

TEST RESULTS:

Test I- With allowable maximum unit stress ($S=17,500$ psi), the working loads P_w are 3.50 t.

Test gave ultimate usefull load $P_u=9.50$ t (see Fig. 7, p. 29). Criterion for "ultimate usefull load" taken, a little hazily, as the load giving signs of lateral buckling.

Test II-

$P_w = 3.50$ t (giving 17,500 psi)

$P_u = 13.10$ t (experimental)

Test III-

$P_w = 4.67$ t

$P_u = 13.0$ t

Test IV-

$P_w = 0$ (since σ_y is already reached at interior support)

$P_u = 13.45$ t

CONCLUSION:

Ultimate "usefull" load is the same in all cases, although P_w vary greatly. Answer to the two questions forming the test objectives:

- (1) The calculated maximum moment at interior support is not critical.
- (2) Deflections of supports have no appreciable effect upon ultimate carrying capacity.

NOTE:

Pretty "hinge" indicated by yield lines in white-wash on Figs. 4b (p. 13) and 6a-b (p. 28).

DATA:

No $M-\phi$ relations given. Given are curves for deflection vs. P at mid-span (Fig. 7, p. 29) and average strain over 4" length at locations e and f (see this summary p. 2) in Fig. 5, p.14.

DISCUSSIONS: (p.274)Grüning & Kulka:

(1) Nothing new - see paper by Grüning "Ultimate Carrying Capacity of Statically Indeterminate Trusses of Steel, subjected to Repeated Loadings", October 1926.

(2) Note: Near bottom of first column, p. 274,

$$Z = bt(h-t) - (h-2t)\frac{2t^2}{6}$$

$$M_p = Z \times \sigma_y$$

(3) As criterion for "ultimate usefull load", use load giving M_p at all critical sections.

(4) Beware of buckling of flanges.

Dr. Bohny:

(1) Be careful in counting on the reserve strength beyond initial yield.

(3) The property of steel, - that yield point is raised and ductility is decreased by repeated (high) stresses -, may perhaps be utilized under certain circumstances.

Metzler

(1) Plastic design may cause large deflections, undesirable on account of, for example, roof covering, plastering, crane runways.

(2) Reserve strength not to be counted on, - needed anyway due to uncertainty of actual loads etc.

Dr. Ing. K. Beyer

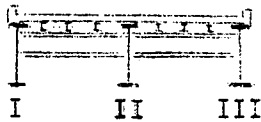
(1) Idea originated by W. Schachenmeier in 1922.

(2) Use only when no dynamic loading and no repeated loadings.

(3) Test also larger sections and built-up girders.

Gaber: Test disprove anxiety concerning the use of statically indeterminate structures.

Krabbe: (1) Test also larger sections and built-up girders.



(2) Discuss application to bridge design - Fig. 2b, p. 277. Girders (or trusses) I, II and III may be made of equal strength.

Bernhard: Removes fear of indeterminate structures, which have not been used to their full extent.

Lineau: (1) In ship structures, stresses above yield point have long been tolerated.

(2) Compare stress-strain properties as determined by Prof. Dalby, England, and others.

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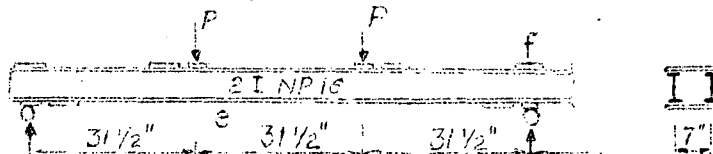
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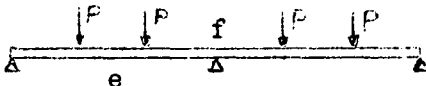
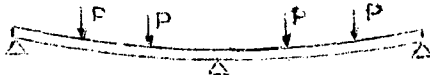
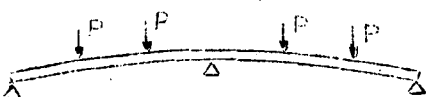


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TEST CONDITIONS: (See Fig. 1, p. 12)

- | | | |
|----------|--|--|
| Test I |  | Simple Beam |
| Test II |  | Three Supports at Same Level |
| Test III |  | Middle Support Lowered to Make Moments at Support and Mid-Span Equal According to Elastic Theory. |
| Test IV |  | Middle Support Raised to Make $M_{\text{support}} = M_y$ Without Any Load on Beam. Beam Was Then Loaded. |

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