1950

Abstract translation of Maier-Leibnitz's "Contribution to the problem of ultimate carrying capacity of simple and continuous beams of structural steel and timber", Lehigh University, (1950)

K. E. Knudsen

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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 Bautechnic, 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 justiby a wider use of statically indeterminate structures as a whole, an effect to which the paper no doubt contributed.

The concepts of Z, 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,

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Asst. Prof. of C. E.

Lynn S. Beedle
Assistant to the Director

LSB:KEK:fs

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CONTRIBUTION 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
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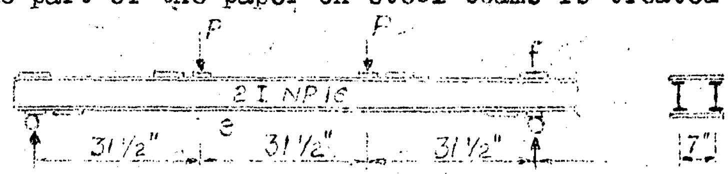
Vol. 6, Feb. 1928

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 Würtemberg, through the Materials Testing Laboratory of the Technical Institute of Stuttgart (Director: Professor O. Graf).

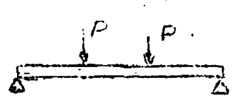
SPECIMENS: (Only the part of the paper on steel beams is treated here.)

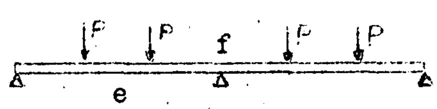


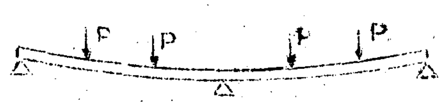
Section Properties	Approximately Corresponding to
2 NP 16	2-6I 12.5
A=2x22.8cm^2(2x3.52in^2)	2x3.61in^2
S=2x 117cm^3(2x7.13in^3)	2x8.8in^2

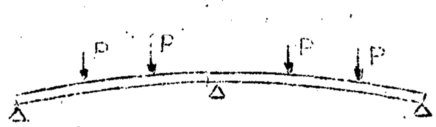
(One test with one I-beam gave lateral buckling.)

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 Elastif Theory.

Test IV  Middle Support Raised to Make $M_{support} = M_y$ Without Any Load on Beam. Beam Was Then Loaded.

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 whitewash on Figs. 4b (p. 13) and 6a-b (p. 28).

DATA:

No M-ϕ 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,

$$Z = bt\ (h-t) - (h-2t)^2 \frac{t_1{}^2}{6}$$

$$M_p = Z \times \sigma_y$$

(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, undesireable on account of, for example, roof covering, plastering, crane runways.

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Dr. Ing. K. Beyer

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

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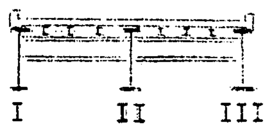

(2) Discusses application to bridge design - Fig. 2b, p. 277. Girders (or trusses) I, II and III may be made of equal strength.

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(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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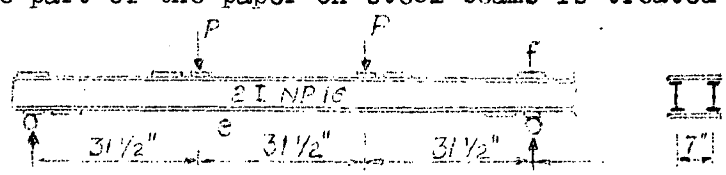

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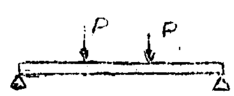

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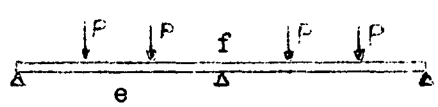

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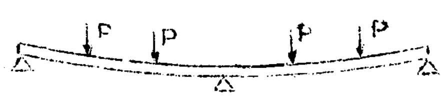

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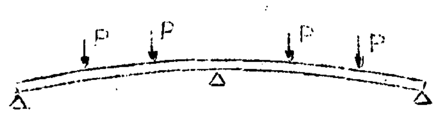

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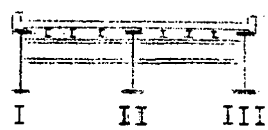

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