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A final report on project 251, welded plate girders, December 1963

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WELDED PLATE GIRDERS

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Fritz Engineering Laboratory Report No. 251.30

A FINAL REPORT
ON
PROJECT 251, WELDED PLATE GIRDERS

Submitted to the

Lehigh University Welded Plate Girder Project Subcommittee

of the Welding Research Council

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INTRODUCTION

The research project "Welded Plate Girders" -- which was carried out at Lehigh University -- was terminated on July 31, 1963 after six and one-half years of existence. The termination signifies the achievement of the original objective of the project, but the research work on welded plate girders is far from complete. Two projects have been initiated; namely,

Fatigue Strength of Welded Plate Girders (303)
Longitudinally Stiffened Plate Girders (304)

each with its specific objective and both closely related to the "parent" project. This final report briefly summarizes the development, phases of work, results and conclusions, list of reports, and other information about the project.

DEVELOPMENT OF THE PROJECT

In the design of plate girders, the buckling strength of a web panel was considered significant in the determination of the strength of the entire girder. The slenderness of a web plate, its width to depth ratio, the restraint at plate boundaries, and the loading condition determine the buckling strength. However, it was also known that the buckling strength is not exactly the strength of a girder. Based on these, the project was initiated by Dr. Bruno Thürlimann

and Dr. Konrad Basler early in 1957 in order to:

1) survey knowledge of the behavior of plate girders with regard to stability and load-carrying capacity,

2) develop a testing program,

3) perform tests and compare results with theoretical predictions,

4) formulate recommendations for the design of plate girders.

The research was guided by the Heavy-Flange Thin-Web Girder Project Subcommittee of the Structural Steel Committee of the Welding Research Council, with Mr. E. L. Erickson as chairman. The title of the Subcommittee was later changed to Lehigh University Welded Plate Girder Project Subcommittee.

Early emphasis of the project work was on the influence of various degrees of flange restraint on web behavior, and on the effect of girder panel geometry and loading conditions on the static load-carrying capacity. Only structural carbon steel girders with transverse stiffeners were considered. As work was carried on, investigations were also made on the behavior and detailing of transverse stiffeners, and girder ends, as well as on partial length coverplates. When the static strength of transversely stiffened girders was analytically determined and experimentally proven, work was then initiated on the fatigue strength of girders, the static strength of girders built of steels with high yield points, and on longitudinally stiffened girders.

After the design recommendations, incorporating the results of the investigations on the static strength of girders, were adopted in actual specifications, the original objective was completed and the project was terminated. The status of the various phases of the project at the time of termination are given below.

PHASES OF PROJECT WORK

Phase	Status	Report
1) Static Strength		
Experimental Study	Complete	251.11, 251.12, 251.13, 251.14
Theoretical Study	Complete	251.19, 251.20, 251.21
Design Recommendations	Complete	251.22, 251.23, 251.25
Guide to Design (Chapter in CRC Guide)	Complete	(Transmitted to Prof. Bruce G. Johnston)
2) Transverse Stiffeners		
Design Detail	Complete	251.6
Experiments	Complete	251.12, 251.13, 251.14
Analytical Study	Complete	251.20
3) Girder Ends		
Theoretical Treatment	Complete	251.20
Experiments	Partially Complete	--
4) Partial Length Cover Plates		
Experimental Study on Stress Transfer	Partially Complete	251.15

Phases of Project Work - Continued

Phase	Status	Report
5) Fatigue Strength		
Experimental Pilot Study	Complete	251.26, 251.26A
Analytical Pilot Study	In Progress	SEE 303
Experimental Investigation	In Progress	--
6) High Strength Steel Girders	Complete	251.29
7) Girder with Longitudinal Stiffeners	In Progress	SEE 304

RESULTS AND CONCLUSIONS

Some of the more important results of the research work are the following:

1) Buckling of a web seldom occurs on steel plate girders. Web buckling strength is not the strength of a girder, neither is the girder load-carrying capacity a linear function of the web buckling load.

2) Depending on the loading conditions of bending, high shear, or their combination, girder strength is governed by the particular behavior of component parts of the girder.

3) The bending strength is determined from the strength of an imaginary compression flange column consisting of the flange proper and an effective width of the web. The resistance of this imaginary column

against the three modes of failure (lateral torsional, and vertical buckling) is therefore of paramount importance.

4) Girder panels under high shear have high post-buckling strengths if adequate transverse stiffeners and boundary supports are provided. Tension fields actually do form, analogous to the tension diagonals of a Pratt truss.

5) Transverse stiffeners can be cut short from the tension flange. A minimum area as well as a minimum rigidity are required to sustain the tension field action.

6) Ends of girders must be strong enough to anchor the tension field action. One way of providing for such anchorage is to add an end plate transverse to the girder web. The other is to place the stiffeners for the last panel so as to prevent a tension field action from developing.

7) The strength of girder panels subjected to both bending moment and shearing force is, in general, governed by either bending or shear alone. Only when the bending stress is higher than 75 percent of the yield point of the girder material and, simultaneously, the shear stress is above 60 percent of that permitted by tension field action, would interaction take place.

8) Methods were developed to predict girder strengths for all the above-mentioned cases of loading. Girder strength can be expressed in terms of the yield point of the girder material and geometrical parameters. The load-carrying capacity predictions are thus applicable to girders built of any presently available

structural steel. Experimental results of 37 tests on 15 full-size girders gave good verification.

9) Stress transfer from flange to a partial-length cover plate is found to be gradual. No sudden increase of stress occurs at the cutoff points.

10) Stress transfer in loading stiffeners is also found to be gradual, being almost linear from the loading end to the opposite end.

11) For a design guide, limits on the web slenderness ratio, panel proportions, stiffener size, rigidity and spacing, and on flange proportioning, were made and incorporated by the AISC in its specification ever since 1961.

12) Incorporating the results of investigations on partial-length cover plates by the project and by other investigators, the Welding Research Council established design rules which were adopted by the AISC.

13) An experimental pilot study on the fatigue strength of welded plate girders showed that the design rules based on static strength can be used as a guide for fatigue considerations. Further investigation of this phase has been developed into a new project.

These results and conclusions are presented in various reports as listed in the Outline of Project Works. A complete list of reports is attached for reference.

SPONSORSHIP AND PERSONNEL

Throughout the years, the financial sponsorship of the project was shared by:

American Institute of Steel Construction (through WRC),
Pennsylvania Department of Highways, and
U. S. Department of Commerce, Bureau of Public Roads,

with other contributions from

Association of American Railroads,
Fort Pitt Bridge Company,
Great Lakes Steel Corporation, and
R. C. Mahon Company.

Those who were engaged in the research work of the project were:

L. S. Beedle
B. Thürlimann
K. Basler
B. T. Yen
P. B. Cooper
J. A. Mueller
H. S. Lew
M. U. Taysi
J. S. Toh

PROJECT INSPIRED RESEARCH

As the results of the project work were made known, various new phases of research on plate girders were generated, such as the projects on fatigue strength of welded plate girders (Project 303) and on longitudinally stiffened plate girders (Project 304). In other institutions, the static behavior and strength of hybrid girders

have been subsequently examined using full-size girders (University of Texas), the fatigue behavior of such girders is under investigation (University of Texas) and the effect of boundary members on the fatigue strength of thin-web girders is being studied using model girders (University of Illinois). Interest has also been created in such foreign countries as England, Belgium and Switzerland.

Project 251 has ended, but, as a ripple travels to the end of a pond and creates a new ring of ripples, so the research on welded plate girders has bred a new family of studies.

REPORT LIST

PROJECT 251, WELDED PLATE GIRDER PROJECT

Report No.	Author(s) - Title - Publication - Date	Comments
251.1	K. Basler & B. Thurlimann LITERATURE SURVEY ON STABILITY OF PLATE GIRDERS, December, 1957	Included in 251.11
251.2	B. Thurlimann STRENGTH OF PLATE GIRDERS, Proc., AISC National Engineering Conference, April, 1958	F.L.Reprint 148,Available
251.3	K. Basler & B. Thurlimann PROPOSAL, January, 1958	To Committee Only
251.4	K. Basler & B. Thurlimann INTERMEDIATE REPORT, January, 1959	To Committee Only
251.5	B. Thurlimann, K. Basler, B.T. Yen & J. A. Mueller PROPOSAL FOR 1959, January, 1959	To Committee Only
251.6	K. Basler & B. Thurlimann PLATE GIRDER RESEARCH, Proc. AISC National Engineering Conference,April, 1959	F.L.Reprint 148,Available
251.7	K. Basler & B. Thurlimann BUCKLING TESTS ON PLATE GIRDERS, Preliminary Report, 6th Congress of IABSE, Stockholm, 1960	F.L.Reprint 155,Available
251.8	K. Basler, STRENGTH OF PLATE GIRDERS (Doctoral Dissertation) October, 1959	Available thru University Microfilms,Inc.
251.9	J. A. Mueller, K. Basler & B. Thurlimann REFERENCE VALUES FOR TEST GIRDERS, January, 1960	Included in 251.11
251.10	K. Basler, & B. Thurlimann BUCKLING PROBLEMS IN PLATE GIRDERS SUBJECTED TO BENDING, January, 1960	Included in 251.19

Report No.	Author(s) - Title - Publication - Date	Comments
251.11	K. Basler, B. T. Yen, J. A. Mueller & B.Thurlimann WEB BUCKLING TESTS ON WELDED PLATE GIRDERS, OVERALL INTRODUCTION AND PART 1: THE TEST GIRDERS, WRC Bulletin No. 64, September, 1960	F.L.Reprint 165
251.12	K. Basler, B.T. Yen, J. A. Mueller & B.Thurlimann WEB BUCKLING TESTS ON WELDED PLATE GIRDERS, PART 2: TESTS ON PLATE GIRDERS SUBJECTED TO BENDING, WRC Bulletin No. 64, September, 1960	F.L.Reprint 165
251.13	K. Basler, B. T. Yen, J. A. Mueller,& B. Thurlimann WEB BUCKLING TESTS ON WELDED PLATE GIRDERS, PART 3: TESTS ON PLATE GIRDERS SUBJECTED TO SHEAR, WRC Bulletin No. 64, September, 1960	F.L.Reprint 165
251.14	K. Basler, B. T. Yen, J. A. Mueller & B. Thurlimann WEB BUCKLING TESTS ON WELDED PLATE GIRDERS, PART 4: TESTS ON PLATE GIRDERS SUBJECTED TO COMBINED BENDING AND SHEAR, WRC Bulletin No. 64, September 1960	F.L.Reprint 165
251.15	J. A. Mueller STRESSES IN COVER PLATES AND BEARING STIFFENERS, WRC Bulletin No. 63, August, 1960	F.L.Reprint 163
251.16	K. Basler FURTHER TESTS ON WELDED PLATE GIRDERS, Proc. AISC National Engineering Conference, June, 1960	F.L.Reprint 164,Available
251.17	B. T. Yen & P. B. Cooper PROPOSAL FOR FATIGUE TESTS ON WELDED PLATE GIRDERS, July, 1960	To Committee Only
251.18	K. Basler & B. Thurlimann BUCKLING TESTS ON PLATE GIRDERS, Final Report, 6th Congress of IABSE, Stockholm, July, 1960	F.L.Reprint 193,Available
251.19	K. Basler & B. Thurlimann STRENGTH OF PLATE GIRDERS IN BENDING, Proc. ASCE, Vol. 87, ST6, August, 1961	F.L.Reprint 210*,Available

Report No.	Author(s) - Title - Publication - Date	Comments
251.20	K. Basler STRENGTH OF PLATE GIRDERS IN SHEAR, Proc. ASCE, Vol. 87, ST7, October 1961	F.L.Reprint 210*, Available
251.21	K. Basler STRENGTH OF PLATE GIRDERS UNDER COMBINED BENDING AND SHEAR, Proc., ASCE, Vol. 87, October, 1961	F.L.Reprint 210*, Available
251.22	K. Basler DESIGN RECOMMENDATIONS FOR PLATE GIRDERS, March, 1961	To Committee Only
251.23	K. Basler NEW PROVISIONS FOR PLATE GIRDER DESIGN, Proc., AISC National Engineering Conference, May, 1961	F.L.Reprint 179,Available
251.24	B. T. Yen & P. B. Cooper PROPOSAL FOR TESTS ON PLATE GIRDERS MADE OF HIGH STRENGTH STEEL, August, 1961	To Committee Only
251.25	B. T. Yen & K. Basler STATIC CARRYING CAPACITY OF STEEL PLATE GIRDERS, HRB, Proc., Vol. 41, 1962	F.L.Reprint 215,Available
251.26	B. T. Yen & P. B. Cooper FATIGUE TESTS OF WELDED PLATE GIRDERS, February, 1962	To Committee Only
251.26A	B. T. Yen & P. B. Cooper FATIGUE TESTS OF WELDED PLATE GIRDERS, AWS Welding Journal, Vol. 42, No. 6, June, 1963	F.L.Reprint 220,Available
251.28	Project Staff PROPOSAL FOR FATIGUE TESTS ON WELDED PLATE GIRDERS, January, 1963	To Committee Only
251.29	P. B. Cooper, H. S. Lew, & B. T. Yen WELDED CONSTRUCTIONAL ALLOY STEEL PLATE GIRDERS, Proc., ASCE ST Journal, December 1963?)	Available
251.30	L. S. Beedle & B. T. Yen A FINAL REPORT ON PROJECT 251, WELDED PLATE GIRDERS, December 1963	To Committee Only

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*F.L. Reprint #210 is a combination of Reports 251.19, 251.20, 251.21 and includes a discussion and closure from ASCE Proceedings Vol. 88, ST2, April, 1962, & Vol. 88, ST5, October 1962, respectively.