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BIBLIOGRAPHY ON BOLTED AND RIVETED STRUCTURAL JOINTS

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CONTENTS

1. A B S T R A C T

In this report are presented abstracts of most of the work that has been performed during the past two decades on riveted and bolted joints. The last major bibliography on this topic was prepared by De Jonge and covered material published before 1944. Altogether 241 abstracts are included. The abstracts are preceded by some historical notes which show the development of fasteners, related materials, research and specifications.

Instructions are provided to aid in the use of this bibliography. Each abstract follows the format recommended by the Engineers Joint Council. A series of graphical summaries are also presented for many abstracts which provide a rapid summary of the type of connection and the variables studied.

In addition to the abstracts, several lists are included for the user. These include the subject and author indexes, a list of Research Council work and a list of references.

2. ACKNOWLEDGEMENTS

The investigation reported herein was conducted at Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pennsylvania. Professor W. J. Eney is Head of the Civil Engineering Department and of the Laboratory. The Research Council on Riveted and Bolted Structural Joints sponsored the research project.

Throughout the work has been guided by the Council's Committee on Bibliography (Mr. R. B. Belford, Chairman and Messrs. J. E. Burke, E. L. Erickson, T. R. Higgins, J. I. Parcel and E. J. Ruble, members). The authors acknowledge their advice and are appreciative of the support of the Research Council in this work.

Sincere appreciation is due Messrs. A. Gopal, J. H. Nieckoski and N. Parikh who prepared many of the abstracts. Special thanks are due to T. Tsuiji who prepared the tables for Section 7, which provide a graphical summary of many of the abstracts; to R. Kormanik who prepared the list of Research Council Reports and the Author and Subject indexes and to J. H. Nieckoski who prepared the list of references.

Thanks are also due Messrs. H. Izquierdo and J. M. Gera preparing the drawings; to Misses Rosalie Fischer and Valerie Austin for typing the manuscript; and to Mr. William Digel for reviewing the manuscript and abstracts.

3. INTRODUCTION

Much valuable research has been performed in recent years on bolted and riveted structural joints, much of which was initiated by the Research Council on Riveted and Bolted Structural Joints, formed in 1947. A list of published Council reports was presented in Ref. 202.* The last major bibliography on this topic was prepared by De Jonge,** covering material published before 1944.

A project was started at Lehigh University in September of 1963, sponsored by the Research Council on Riveted and Bolted Structural Joints (hereafter referred to as "the Research Council, or, RCRBSJ"), to prepare a bibliography on bolted and riveted structural joints. It was considered that such a bibliography would fill a number of functions. It would be useful to structural engineers and others who need ready access to the material published since 1944, especially to those concerned with the high-strength bolts which have come into use in the past seventeen years. It would provide researchers with summaries of past work to guide them in formulating new projects. Furthermore, it would help eliminate unnecessary duplication of literature searches in this field.

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* Numbers refer to abstracts and list of references.

** De Jonge, A. E. R., "Riveted Joints: A Critical Review of the Literature Covering Their Development", ASME, New York, 1945.

The initial emphasis was on Council-sponsored work. Important articles and reports published by others were abstracted if the publishing agency did not provide suitable abstracts. Because bolted joints have been more extensively investigated than riveted joints in the past two decades, most of the material selected for this bibliography deals with them. The coverage extends in time from 1944, taking up where De Jonge stopped, to June 1964. Articles published since January 1964 in the Journal of ASCE have had suitable abstracts prepared as this was when the ASCE information retrieval program was begun. Most of the articles described herein were reported in the English Language. A subsequent report will provide information on foreign literature.

When the project was started it was not anticipated that the results of the research reported in the various articles would be evaluated. However, in the following section some historical notes are presented which show the development of fasteners, related materials, research, and specifications.

Following the section concerned with "historical notes" is a section on procedures for use in the bibliography. These follow the abstracts proper and tables which provide a graphical summary of papers (types of tests and variables studied). The remainder of the report consists of aids in using the material. Section 8 is a list of Council reports. Author and subject indexes follow. The appendixes contain Council objectives, membership and discussion of specification. The final item is the listing of references. The use of these materials is described in the section, "Procedures for Use."

4. HISTORY OF RIVETED AND BOLTED JOINTS

Most of this section is concerned with the developments in riveted and bolted joints during the past twenty years. The work before this period is mentioned only briefly because a detailed review and discussion of it is readily available in De Jonge's bibliography.

The possibility of using high-preload bolts in steel-framed construction was first demonstrated by Messrs. Batho and Bateman in their report included in the publication of the second report of the Steel Structures Research Committee in 1934.* Extensive laboratory tests were conducted and reported. It was concluded that bolts with a minimum yield strength of 54 ksi could be tightened sufficiently to give an adequate margin of safety against slip of the connected parts. It was recommended that the bolts be installed with a torque wrench in order to insure the attainment of the preload.

Subsequent tests on high-strength bolts performed at the University of Illinois by W. M. Wilson were reported in 1938.** It was concluded from the test results that "the fatigue strength of high-strength bolts appreciably smaller than the holes in the plates, was as great as that of well-driven rivets if the nuts were

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* Batho, C. and Bateman, E. H., "Investigations on Bolts and Bolted Joints", Second Report of the Steel Structures Research Committee H.M. Stationary Office, London, 1934.

** Wilson, W. M. and Thomas, F. P., "Fatigue Tests on Riveted Joints", Bulletin No. 302, University of Illinois Engrg. Experiment Station, 1938.

screwed up to give a high tension in the bolts".

In 1945 Maney[12] reported on studies of single bolts and how to predict the bolt preload. At about the same time he began a research project directly related to bolted connections[9]. In a few preliminary tests the structural behavior of bolts torqued into the inelastic region was unimpaired. The results of these studies were reported in Ref. 24.

The Research Council on Riveted and Bolted Structural Joints, formed in 1947, provided the impetus for the rapid development of the high-strength bolt in the United States. The Council sponsored studies of high-strength bolts and of their use in structural connections. Also contributing to the development of the high-strength bolt at this early stage was the American Railway Engineering Association. Under AREA sponsorship Wyly and Carter in 1948 were studying the problem of fatigue failures of floor beam hangers of railway bridges[25]. The hypothesis was advanced that these failures were due to high stress and strain induced by rivet bearing, and a high-clamping-force bolt was proposed as a means of minimizing the effect of bearing. This hypothesis was verified and reported in Ref. 97.

The AREA initiated studies on the possibility of using high-strength bolts in bridge maintenance, and the Association of American Railroads began a program of field installations and feasibility studies[29][33]. The earliest installation was in 1948 in a bridge of the Pennsylvania Dock Co., at Ashtabula, Ohio. This program confirmed the adequacy of the behavior of bolted connections under load.

The American Society of Testing Materials is conjunction with the Research Council prepared a tentative specification for the materials for high-strength bolts, a specification which was approved in 1949 and revised in 1951 under the ASTM designation A325.

A symposium on high-strength bolts was presented at the Engineering Conference of the American Institute of Steel Construction in 1950. The results of the studies reported in Refs. 28, 29, and 30 were summarized. Also discussed was some of the work being sponsored by the Research Council. Using the results of its research[34] and other information, the Research Council prepared and issued its first specification in January 1951. This specification allowed the bolt to replace the rivet on a one-to-one basis.

By 1952 a number of laboratory and field investigations had been completed and the results were presented at a symposium on high-strength bolts at the Centennial Convention of ASCE at Chicago[91][92][95][96][97][98]. Steward[91] summarized the Research Council's activities and presented a brief resume of the development of high-strength bolts in the United States. Munse, Wright, and Newmark[94] summarized the results of static and fatigue tests on small bolted structural joints. These tests confirmed earlier studies which indicated the superiority of high-strength bolts over rivets. Additional tests comparing the static and fatigue strengths of bolted and riveted joints were reported by Baron and Larson[95]. An extensive series of tests were described by Hechtman, Young, Chin, and Savikko regarding the slip characteristics of bolted joints under static loads[96]. Carter, Lenzen, and Wyly[97] presented test results to support a hypothesis for the cause of and remedy for fatigue failures in structural joints. It was shown that fatigue strength decreases as bearing stress increases and that the fatigue strength of bolted joints exceed the fatigue strength of riveted joints. Higgins and Ruble[98] reviewed the behavior of mechanically fastened joints; described the development of high strength bolts; and discussed tightening procedures, costs, and recent developments.

A number of studies of "joint efficiency" were reported in 1952. Wilson, Munse, and Cayci[55] summarized results of completed tests and reported on a program of tests. This was followed by extensive tests of small joints and the formulation of empirical rules by Schutz[56]. This study indicated that a much closer correlation was obtained with the proposed "relative gage" method than with any previous method.

Additional studies to determine the strength of hot-driven rivets subjected to combined shear and tension were summarized, and an empirical interaction curve was given by Higgins and Munse in 1952[59]. Previous investigations had not covered the full range of shear-tension ratios.

An extensive investigation which included many tests of riveted double-shear aluminum joints was reported by Francis in

1953[64]. Theoretical solutions were presented for the elastic and inelastic ranges. Although it was concerned specifically with aluminum joints, this study contributed significantly to the knowledge of the behavior of all double-shear splices.

Minor revisions based on the Research Council's continuing research program[34][65] were incorporated into the revised specification issued in February 1954. In December 1955 an appendix was issued to answer questions concerning the application of the specification.

The first German research work was reported in 1954 by Steinhardt and Mohler[242]. Sufficient experience and knowledge had been gained through laboratory work, field studies, and reports of American practice to enable the German Committee for Structural Steelwork to issue a preliminary Code of Practice in November 1956[243]. After additional research had been performed and the behavior of structures in the field had been evaluated, this preliminary Code of Practice was revised and issued as a Code of Practice in 1963.

Tests at the University of Illinois in 1954[74] demonstrated that high-strength bolts tightened well past their yield strength and then subjected to tension were not adversely affected[107].

Pre-tension control was the subject of several more recent investigations. The use of pneumatic impact wrenches was found to reduce field labor costs. The development of wrench calibrators led to the use of calibrated wrenches to provide bolt tension. In 1955

Drew[66][85] reported on studies of several methods of tightening high-strength bolts and the development of a one-turn tightening method. This resulted in a one-full-turn-of-the-nut-from-the-finger-tight pretensioning procedure being approved by the Research Council and included in the Appendix distributed in 1955. Additional studies reported by Pauw[83][86] supported this procedure.

The results of studies on the effect of bearing ratio on riveted joints subjected to static loads were summarized by Jones in 1956[104]. This paper showed that joint strength will not be reduced if bearing stresses are increased. Additional test results supporting this conclusion were published by Munse in 1957[144]. Studies of the behavior of large I-section connections were reported in 1955[82]. Tests of riveted connections in truss-type members were described by Chesson and Munse in 1957[132].

Considerable interest in the slip behavior and ultimate strength of large bolted connections led to several preliminary tests of A7 steel bolted butt splices[75][80][95]. These tests all indicated that the strength of the fasteners in shear far exceeded the strength of the net section. In 1957 a test was performed on an A242 steel joint connected by A325 and A354 bolts[113]. An extensive research program was begun at Lehigh University in 1957 "to study the behavior, under static tension loads, of large plate joints connected with high-strength bolts to determine if fewer bolts may be used than required by specification". The results of the first phase, reported by Foreman and Rumpf in 1958[133], indicated that the 1954 design specification was unduly conservative when slip into bearing could be permitted.

In 1958 a second symposium was sponsored by the Research Council during the meeting of ASCE in Chicago. A summary of Council-sponsored investigations and a list of Published Council reports was given by Ruble[202]. Munse, Peterson, and Chesson presented results of tests to determine the behavior of connections in which the rivets and bolts carried loads in tension[203]. Douty discussed these tests[204] and presented an approximate analysis[119]. Tests to determine the moment-rotation characteristics of standard web angle connections were described by Munse, Bell, and Chesson[207]. The specimens were similar to the riveted connections tested by Hechtman and Johnston[15]. Hanson presented the results of numerous fatigue tests of joints of high-strength steels[208]; joints connected with high-strength bolts had higher fatigue strengths than those connected by rivets. The type of connected steel had little influence on fatigue strength. The effects of punched holes, misalignment, painted faying surfaces, bolt tightening method, and faying surface conditions on the slip and ultimate strength were reported by Vasarhelyi et al[209]. Ball and Higgins reported on studies and tests made to develop a modified turn-of-nut procedure[210] and the procedures developed for the bolt installation of the Mackinac Bridge was reported by Kinney[216].

In the United Kingdom, the general practice was to follow the American practice and specifications. In 1959 a symposium on high-strength bolts was organized by the Institution of Structural Engineers. The results of laboratory and field experience were presented. Abstracts of the symposium papers are given in Refs. 147 to 161. The British Standards Institute formed a committee to prepare a directive on design procedure and field practice. The Institute issued British Standard 3139 in 1959[244]. Dealing only with bolt material, it is almost identical to ASTM A325. In 1960 British Standard 3294[245] was issued to establish design procedure and field practice.

Several papers concerned with moment connections using high-strength bolts were published in 1959[151][155]. Different schemes for bolting interior beam-to-column connections were tested. It was shown that bolted connections could be designed to develop the plastic moment of the connected material. There were no premature failures except those which could have been predicted and prevented.

Chesson and Munse in 1959 reported on additional studies of large riveted and bolted truss-type connections[164] similar to the riveted connections reported on in 1957[132]. The results of tests of a riveted plate girder with a thin web were reported by Vasarhelyi, Taylor, Vasishth, and Yann[181].

Several studies of the behavior of single bolts during tightening and calibration were reported in 1959. Bendigo and Rumpf reported on extensive calibration studies of single bolts[169].

Load-rotation and load deformation characteristics were discussed. A preliminary report on relaxation tests of high-strength bolts by Lewitt, Chesson, and Munse[170], indicated that losses due to relaxation are small. Additional tests reported by Lewitt, Chesson, and Munse in 1960 showed that a hardened washer is not needed to prevent minor bolt relaxation resulting from the high stress concentration under the head or nut of the heavy-head A325 bolt[174]. Tests to determine the double-shear strength of single A325 bolts were reported in Refs. 137 and 142.

Due to the completion of extensive tests after the issuance of the 1951 and 1954 specifications, the Research Council completely revised its specification in 1960. Studies of the heavy structural bolt[174] installed without hardened washers indicated that its performance under static and fatigue conditions is equal to that of the regular semi-finished bolt then in use with hardened washers. As a result, the new specification permitted the elimination of the washer at the bolt head or nut, whichever was not turned in tightening. For the first time since the introduction of the high-strength bolt, it was officially recognized that bolts have strength properties superior to those of rivets. Up to this time, design of bolted structural connections had followed the design for rivets with bolts substituted for rivets on a one-for-one basis. New design rules for bearing-type connections based on research at Lehigh University[175][201] established increased bolt shear stresses. The tests indicated that shear must be through the body and not through the threads to realize the full strength of the bolt. Also, because of the desirability of high preload the required minimum tension[183] was increased to the bolt proof load. Allowable stresses in tension were increased substantially, for tests demonstrated that bolt fatigue strength under this loading condition was not adversely affected[203]. The installation procedure for the turn-of-nut method was modified after extensive development by Bethlehem Steel Co.[127][210]

In 1960 Rumpf[191] adapted the methods described by Francis[64] to bolted bearing-type joint of A7 steel. Excellent correlation was obtained between the theoretical values and the experimental data. In 1961 Hansen used Rumpf's analytical method in determining the effect of pitch in ten hypothetical joints[199]. Also, Hansen and Rumpf reported several tests of large bolted connections[200].

Additional studies at Cambridge University of bolted beam-to-column connections were reported by Sherbourne in 1961[195] and extended the work reported earlier by Johnson, Cannon and Spooner[155]. A major investigation of high-strength bolted connections in plastic design was initiated at Cornell University in 1960. Part of this work was reported by Douty and McGuire in 1963[231].

Tests conducted at the University of Illinois to determine the effect of the elimination of both washers on the static and fatigue strength were reported by Knoell, Chesson, and Munse in 1962[218]. This study showed no significant reduction in strength as a result of omitting washers. Additional bolt calibration studies of heavy-head bolts were reported in Ref. 217.

Because of the continuing research the Research Council specification was updated in 1962. Washers were no longer required[225]. Tightening procedures were modified as a result of the additional calibration studies[217][233].

The results of tests on bolted lap joints and large riveted joints were reported in 1962[221][224]. A few calibration and relaxation tests of A354 bolts were reported by Chesson and Munse[227]. Calibration tests were begun at Lehigh University on A354 bolts having dimensions similar to the heavy-head A325 bolts. Preliminary results were presented by Christopher and Fisher in 1963[229].

The results of a number of investigations conducted at the University of Illinois were published by ASCE in 1963. (Abstracts are provided with the published reports and are not repeated here.) Lewitt, Chesson, and Munse described the fatigue behavior of bolted connections[246]. Consideration is given to joints assembled with bolts subjected to shear-type loadings and to direct tensile loading. Chesson and Munse reported on extensive tests of truss-type tensile connections[247]. Several analyses of joint efficiencies are described and compared with test data. A subsequent report by Munse and Chesson[248], further discusses the factors which affect the behavior of connections and presents an empirical method for computing joint efficiency.

Bendigo, Hansen, and Rumpf published the results of tests of long bolted A7 steel joints and riveted joints in 1963[249]. It was shown that in longer connections, end bolts sheared before all bolts could develop their full shearing strength. The results of tests of A440 steel joints connected by A325 bolts were reported in the same year by Fisher, Ramseier, and Beedle[234]. Also, the calibration studies reported in Refs. 169 and 217 were published by Rumpf and Fisher[250].

A criterion for designing bearing-type connections was proposed in 1963 by Fisher and Beedle[228], who pointed out that the balanced design concept has little meaning. It was proposed that allowable stresses be based on the shear strength of the fastener.

Chiang and Vasarhelyi[232] reported on tests involving misaligned holes in bolted joints. It was concluded that misalignment has little or no effect on joint strength. Miscellaneous studies of A325 and A354 bolts summarized by Chesson and Munse[233] included relaxation tests, determining the effect of sloping surfaces on turn-of-nut installation, and fatigue studies of bolted connections without washers.

A report of progress of the Cornell University work on the plastic design of bolted connections was presented by Douty and McGuire in 1963[231]. The essential feature in the results of the beam-to-column connection tests is that the connections were able to carry the plastic moment and rotate inelastically through a very large angle. Tests of beam splices showed similar results. In fact, the actual buckling failure occurred outside the connection in the member itself.

A recent report by Beedle and Christopher(251) summarized tests of bolted connections reported in abstracts 143, 155, 195, and 231.

Chiang and Vasarhelyi(236), reported on tests of small joints to determine the coefficient of friction. A36, A440, and T1 steels were studied. A basic friction test is also discussed and compared with the results of the bolted connection tests.

Recently Fisher(235) developed mathematical models which established the relationship between deformation and load throughout the elastic and inelastic regions for the component parts of bolted butt splices. A digital computer program was developed for the solution of bolted plate problems in order to make practicable what otherwise would be too tedious. The solution was used to study the effect of joint length, pitch, variation in fastener diameter, and variations in the relative proportions of the bolt shear area.

The results of tests of single high-strength bolts under combined tension and shear were reported by Chesson, Faustino, and Munse(238). Most of the tests were conducted on A325 bolts, but a few tests of A490 bolts were included. The interaction eclipse presented is similar to that described earlier for rivets(59).

The results of calibration tests of A490 bolts are reported in Refs. 237 and 239. These tests at Lehigh and the University of

Illinois were made on bolts taken from the same lot. The tests, conducted to determine whether testing procedures constitute a variable, were in close agreement.

As a result of the studies conducted on A354 and A490 bolts[229][233][237][238][239], the Research Council revised its specification again in 1964 to include both A325 and A490 bolts.

5. PROCEDURES FOR USE

1. ABSTRACTS

The abstracts in Section 6 present comprehensive, factual, and concise information distilled from important articles, reports, papers, and other publications. They indicate as clearly as possible the contents of the original publications. Each abstract is printed in the middle of a special card-type format designed to facilitate its use. Each contains the four essential parts recommended by the Engineers Joint Council and used by the ASCE.* (Bibliographic information, abstract, key words, and an accession number.) The only modifications in the ASCE model format are the arrangement of the parts and the addition of a bibliographic number.

Complete bibliographic information is included with each abstract so that the reader who needs additional information can find the original publication. This information appears at the top of the abstract and is listed as author, title, and source. The author's name is placed first because searchers are often familiar with the names of those working on a particular topic. The title is shown next. All sources for each item are listed: the principle source is listed immediately following the title and the other sources are enclosed in brackets after the principle source. Articles published

* "ASCE Moves Towards More Efficient Information Retrieval", Civil Engineering, Vol. 32, No. 8, August 1962, p. 42.

by the ASCE in the Transactions are listed as principle sources even though they first appeared elsewhere. Original reports issued by universities and other agencies are included in the bracketed sources.

At the bottom of the abstract format is a list of key words or descriptors which indicate the contents of the item and are actually used by the author. They are provided as an aid in listing individually-assigned accession numbers on the appropriate key-word cards. Although they reflect each important concept in an article, they are not of equal importance.

The abstract number assigned in this bibliography appears in the bottom right-hand corner. These numbers are used for reference in the introduction, the graphical summary tables, and the author and title indexes.

Each abstract can be cut out and pasted on a 3 x 5 in. file card and included in a personal reference system. A document-accession number may be placed in the box provided in the upper-right-hand corner of each abstract card. The card file may also be used for abstracts from other sources. It is likely that some abstracts will appear in a similar format.

The file can be made more useful with the key-word system described in the CIVIL ENGINEERING reference mentioned previously. The article, which also offers information on setting up files and recommends adhesives, should be read by anyone who intends to make a file of abstract cards.

2. LIST OF REFERENCES (BIBLIOGRAPHY)

This list uses the same reference numbers as do the abstracts. It is provided as a convenience to the reader for quick access to the essential bibliographic information, but contains no information not already included in the abstract format.

Its location at the very end of the report is, again, a matter of convenience for quick reference in this particular present format of the report.

Following Ref. 241 are those references for which no abstracts are included, most of them being available elsewhere.

3. TABLES

The tables are designed to give a panoramic view of aspects of mechanically-fastened joints. The "Ref. No." is the same as that used in "Abstracts" and "List of References". The condition studied in the particular article is described by sketch, as to medium and type, and as to variables studied. Additional notes are provided as appropriate.

4. RESEARCH COUNCIL REPORTS

The list of Council reports is presented for information. It records those reports that were prepared either under the general Council auspices or in connection with the work of a particular project of the Council.

A word of explanation is in order about designation of projects. Prior to 1960 the research work of the Council was conducted according to projects. After this date "Committees" were designated to act more on a task basis. Because work on some of the "Projects" was still underway, new "Committees" were set up to guide the continuing work. In such instances, the roman numeral in parenthesis following the Committee number is a designation of the former "Project" number.

5. INDEXES

The author and subject indexes follow standard format. The numbers designate abstracts.

6. ABSTRACTS

The abstracts in this section appear in chronological order. Complete bibliographic information is included with each abstract.

Maney, G. A.
CLAMPING FORCE. . . .THE SILENT PARTNER IN RIVETED JOINT DEPENDABILITY, Fasteners, Vol. 1, No. 2, 1944, pp. 12-14.

This paper is a review of German research into the importance of clamping force in riveted joints. For plain carbon steel rivets, a large percentage of the applied load is carried by the clamping frictional forces and hence the rivet may never be loaded in shear. In alloy steel rivets the desired clamping force may not be realized with certain alloys. The clamping force must stay close to the elastic limit load if it is to be effective. There is an increase in the strength of steel rivets with the working of the rivet but there is a subsequent decrease in clamping force.

KEY WORDS: design; force; clamping; joints; rivets; steel

(1)

Stewart, W. C.
WHAT TORQUE? Fasteners, Vol. 1, No. 4, 1944, pp. 8-10.

Factors which influence the attainment of fastener tension by use of torque are discussed. The torque-tension ratio is recognized as a very important factor in fastener assembly. The theoretical torque-tension ratio for bolts or screws does not hold in practice due to frictional and other effects. The effects of friction and faying surface configuration are analyzed.

KEY WORDS: bolts; design; joints; torque

(2)

Wilson, W. M.
DO RIVETS RETAIN THEIR INITIAL TENSION? Civil Engineering, Vol. 14, No. 10, October 1944, pp. 437-438.

Forty-year-old short deck-plate girders were removed from a railroad bridge and tested to determine the tension in the rivets. The tests showed that some rivets retained considerable tension, while other rivets were under almost no tension. Since the original tension at the time the rivets were driven was not known, no qualitative correlation could be made. The author finds it reasonable to suppose that layers of paint on all contact surfaces might be responsible for an appreciable reduction in rivet tension.

KEY WORDS: recovery; rivet; tension

(3)

Maney, G. A.
BOLT STRESS MEASUREMENTS BY ELECTRICAL STRAIN GAGES, Fasteners, Vol. 2, No. 1, 1945, pp. 10-13.

A test method using SR4 strain gages is described that will measure the tensile or clamping force strains in the bolt, the torsional shearing strains that result from friction drag on threads, and the direct transverse shear stress in the bolt. Relations between the clamping force or axial tension stresses and the torsional shearing stresses were proposed. It is shown that the reversal of applied torque at the end of a tightening operation can reduce the torque induced in a bolt by the tightening operation to about zero without affecting the clamping fo-ce.

KEY WORDS: bolts; electrical measurements; joints; strains; stresses

(4)

Fasteners
COLD RIVETING GAINS ACCEPTANCE, Fasteners Vol. 2, No. 3, 1945, pp. 16-17.

A short history of the cold driving process is given. The requirements for the process and the expected properties are evaluated. It is suggested that with properly controlled pressure, cold driving of large rivets offers a number of advantages. Holes are completely filled, caulking against leaks is unnecessary, rivets attain superior physical characteristics, and the cost is reduced by elimination of heating and easier handling of cold rivets.

KEY WORDS: fabrication; riveting, cold; rivets

(5)

Crocker, S.
BOLTING FOR PIPE FLANGES AND PRESSURE VESSELS, Fasteners, Part 1, in Vol. 2, No. 4, 1945, pp. 4-7, and Part 2, in Vol. 3, No. 1, 1946, pp. 16-18.

The basic practices developed during the past twenty years in bolting pipe flanges and pressure vessels are described. Each application of pipe flange bolting usually requires one or more distinctive features to suit conditions peculiar to making pressure-tight flanged joints. Provisions for these features have been incorporated into the various American standards and ASTM specifications for bolting. This review is presented as a guide for following these provisions.

KEY WORDS: design; fabrication; specifications

(6)

Frankland, F. H.
MORE EFFECTIVE USE OF RIVETS AND BOLTS, Engineering News Record, March 7, 1946, pp. 85-87.

The development of rivet and bolt steel for specific uses is discussed. The requirements for rivet steel, specifications for bolt steel, and a technique for cold driving are discussed. At the time of writing, it was suggested that the additional strength of a joint due to clamping force should be taken into account in conventional design methods or specifications. The use of a "rivet-bolt" in which the principles of both rivet and a bolt are combined in one fastening is described.

KEY WORDS: bolts; rivets; riveting, cold; shear stress; tension

(7)

Jackson, L. R., Wilson, W. M., Moore, H. F., and Grover, H. J.
THE FATIGUE CHARACTERISTICS OF BOLTED LAP JOINTS OF 24S-T ALCLAD SHEET MATERIALS, NACA, TN 1030, October, 1946.

The effect of bolt fit on the life time of lap joints of 24S-T Alclad sheet joined by steel bolts and designed for sheet failure under repeated loading is determined. Tests conducted include tension-tension and tension-compression on specimens assembled with one or more bolts having uniform fit. The fit was varied from "press-fit" to a "sloppy fit". Altogether, 501 tests in undirectional loading and 209 tests in reversed loading were made at the Battelle Memorial Institute and at the University of Illinois. About 109 auxiliary tests were performed to evaluate the effect of factors such as type of bolt, bolt torque and bolt size. It appears that the effect of bolt fit is slight on joint life time under undirectional loading and under reversed loading. But loose-fitting bolts results in slip and joint deflection and consequently are undesirable. The use of two or more bolts in line increases the fatigue strength but not in direct proportion to the number of bolts. For the bolt pattern and bolt diameter tested, the fatigue strength of bolted lap joints does not increase in proportion to sheet gage (thickness).

KEY WORDS: bolts; fatigue; lap joints; loads; sheet

(8)

Maney, G. A.
REPEATED LOADS ON RIVET JOINTS, Fasteners, Vol. 3, No. 2, 1946, pp. 14-15.

A detailed description is given of a fatigue testing machine built to test riveted joints. The 250,000-pound-capacity machine is modeled after a similar walking-beam machine at the University of Illinois.

KEY WORDS: bolts; fatigue; joints; steel; testing machine

(9)

Frankland, F. H.
RIVETS AND BOLTS IN STRUCTURAL DESIGN, Fasteners, Vol. 3, No. 3, 1946, pp. 4-6, 18.

The requirements for structural rivet steel and structural bolt steel, and the ASTM specifications for rivet and bolt steels are discussed. The use of cold-driven rivets is analyzed and the effects of cold-driving on the rivet steels are noted. Several design considerations concerning clamping force, rivet material and bolt material are presented.

KEY WORDS: bolts; joints; rivets; structural design

(10)

Maney, G. A.
WHAT HAPPENS WHEN A BOLT IS TWISTED OFF? Fasteners, Vol. 3, No. 4, 1946, pp. 12-16.

The "twist-off" type of bolt failure, commonly believed to be a torsional shear failure, is shown to be a "pull-off" failure caused by the axial elongation of the threaded section of the bolt which in turn causes a mismatch of threads and an increase in friction between bolt and nut. An experimental technique for investigating this type of failure is presented.

KEY WORDS: bolts; failure; joints

(11)

Maney, G. A.
PREDICTING BOLT TENSION, Fasteners, Vol. 3, No. 5, 1946, pp. 16-18.

This study indicates that a predictable relationship exists between applied torque and bolt tension for low carbon steel bolts. An empirical equation is given to express this relationship. However, the relationship is only approximate because the bolt tension in a group of bolts may vary by plus or minus 30 per cent.

KEY WORDS: bolts; tension; torque

(12)

Tate, M. B., and Rosenfeld, S. J.
PRELIMINARY INVESTIGATION OF THE LOADS CARRIED BY INDIVIDUAL BOLTS IN BOLTED JOINTS, NACA, TN 1051, 1946.

A general solution is presented for the determination of loads carried by individual bolts in symmetrical butt joint. With the help of expressions given for bolt behavior, the general solution is applied to calculate bolt loadings in joints made of any combination of materials common to air plane construction. Six symmetrical butt-joint specimens - three of the two-bolt joints and three of the three-bolt joints-were fabricated and tested to check the applicability of the theory. The test specimens were made of 24S-T aluminum-alloy plates fastened by two or three 1/4 in. alloy steel bolts with the bolts in a single line in line with the applied load. Curves are drawn to show bolt-load histories through the elastic and yield ranges to joint failure. Curves are also drawn to represent bolt action above the upper limit of elastic action. These curves combined with analytical equations provide a means for the prediction of bolt loads at any joint load.

KEY WORDS: bolts, loads, static; plates, aluminum-alloy

(13)

Pancoast, R. H.
THE EFFECT ON BOLT SHEARING STRENGTH OF VARIOUS AMOUNTS OF TENSILE STRESS SIMULTANEOUSLY APPLIED, B. S. Thesis, Fenn College, May 1947.

An attempt is made to determine the best combined unit stress for use in design considerations of a bolt in combined shear and tension. By varying the angle between the applied load and the bolt axis, the applied stress was varied from pure shear to pure tension. The results of 57 tests led to the conclusion that the maximum shearing stress is the proper combined unit stress for design use.

KEY WORDS: bolts; design; shear stress; tension

(14)

Hechtman, R. A., and Johnston, B. G.
RIVETED SEMI-RIGID BEAM-TO-COLUMN BUILDING CONNECTIONS, Committee on Steel Structures Research, No. 206, AISC, November, 1947

Forty-seven riveted semi-rigid beam-to-column connections were tested at Lehigh University and the results interpreted for the development of a simple design procedure. Standard beam web angle connections and top and seat angle connections were investigated. Results showed that connections on each side of the column web, when tested against each other, were somewhat stiffer than similar connections to the column flange. It was also found that the rivet pattern of the tension rivets in the vertical leg of the top angle influenced the behavior of the connections. Also included is a suggested supplement to the AISC Specification for Structural Steel for Buildings to cover semi-rigid beam-to-column connections.

KEY WORDS: design; joints, beam-to-column; rivet; pattern

(15)

Millard, E. H.
HALF A CENTURY OF COLD RIVETING, Fasteners, Vol. 4, No. 1, 1947, pp. 7-9.

"A review is presented of the history of the cold riveting process, including applications, design considerations, economy, and advantages and disadvantages.

KEY WORDS: joints; rivets; riveting, cold

(16)

Hill, H. O.
DOES TORQUE WEAKEN BOLTS? Fasteners, Vol. 4, No. 1, 1947, pp. 10-12.

Tests were conducted at Lehigh University, Bethlehem, Pennsylvania, to determine the reduction in tensile strength when bolts are torqued slightly beyond the yield point of the material. The test data presented indicates that when bolts are torqued to failure, the ultimate strength in tension is reduced by 25 to 32 per cent of their value in pure tension. When bolts are torqued to any degree short of failure, they still maintain their original tensile value for resistance to external load. The tests were made on 5/8 and 3/4 inch diameter galvanized bolts 11 inches long. The threads of the bolts were cut, class 2, coarse thread, series; and the hot-formed heads were square. The nuts were hexagonal. Carbon in the bolts was 0.15 to 0.24 per cent. Tension was applied between the head and nut by either the straight pull of a testing machine, tightening of the nut, or a combination of these two.

KEY WORDS: bolts; failure; torque

(17)

Vogt, F.
THE DISTRIBUTION OF LOADS ON RIVETS CONNECTING A PLATE TO A BEAM UNDER TRANSVERSE LOADS, NACA, TN No. 1134, 1947.

Presented are three theoretical methods of solution for the distribution of loads on rivets connecting a plate to a beam under transverse loads: in the first, rivets are treated as discrete members; in the second, they are replaced by a continuous system of jointing; and in the third, non-linear deformations occur in the rivets and the plate, but not in the beam. The methods are illustrated by numerous examples. These methods could be used in the design of light alloy structures where the design load is well above the limit of proportionality.

KEY WORDS: analyzing; design; distribution, load; rivets

(18)

Langdon, Howard, H., and Fried, Bernard
FATIGUE OF GUSSETED JOINTS, NACA, TN 1514, September, 1948.

Fatigue tests were made on 46 gusseted joints to determine the effect of gusset edge finish on fatigue life and to compare riveted with spot-welded assemblies. Neither finish was found to have any effect on the fatigue life of either the 24S-T or the heat-treated alloy steel (X 4130-AN-QQ-S685, yield strength = 180,000 psi) gussets tested. The riveted 24S-T joints had better fatigue characteristics than the spot-welded 24S-T joints.

Additional data obtained in these tests and in a supplementing photoelastic study of the riveted-joint assembly indicated that at low load cycles, stresses set up in the gusset during the riveting operation affect the fatigue life of the gusset. At high load cycles fatigue life is governed by the geometry of the gusset, that is, stress concentration at the rivet holes. Results showed that stresses introduced across the center section of the gusset by the riveting operation may reach values as high as 50 per cent of the tensile stress. These tests indicate that gusset designs should be improved.

KEY WORDS: alloy steel; aluminum alloy; fatigue life; joints, gussetted; rivet

(19)

Grinter, L. E.
STRESSES IN GUSSET PLATES BY USE OF AN ANALOGOUS GRID (WITH APPENDIX ON PROBLEM ANALYSIS by Marvin Mass), IABSE, September 1948.

An analytic model of a gusset plate is developed, based on the similarity of a gusset plate continum to the grid of a mutiple storied frame. The grid analogy, making use of the physical concepts found in the analysis of structural frameworks, provides a method by which structural designers may approximate the stress in a gusset plate if they know the point forces applied by the fasteners. Since the partition of load in the fasteners is not a consideration in this analysis, the approximation of the stress condition is valid only some distance away from the point of application of the load. A square plate symmetrically loaded is solved as an example.

KEY WORDS: fastener; gusset plate; stresses

(20)

Kelly, J. J.
DESIGN FACTORS FOR THREADED FASTENERS, Fasteners, Vol. 5, No. 1, 1948, pp. 16-18.

A discussion is presented of the factors to be considered in designing bolts to function properly as threaded fasteners. The use of yield strength data is compared to the use of values called "elastic proof load". The relationship of bolt size to hole size is discussed; it is concluded that the actual body dimension should be equal to, or preferably less than the basic size of the hole. The diameter of the thread, taken to be midway between the root and pitch diameters, limits the ability to carry load. The radius of the fillet under the head of the fastener determines the stress concentration and is controlled by the size of the hole in the members and the size of the body diameter. The factor of thread fit is also discussed.

KEY WORDS: bolts; design; fasteners

(21)

Lipson, Charles
DISIGNING BOLTS TO RESIST SHOCK LOADING, Fasteners, Vol. 5, No. 3, 1948, pp. 4-6.

The design of bolts to resist shock loading is reviewed. The effects of the following factors on such designs are analyzed: bolt tightening, rigidity of bolted members, bolt life, bending loads, rounding off the root of the thread, diameter of the shank vs. diameter of the thread, length of free thread, runout angle of the thread, radius under the bolt head, and stress relieving of notches on this design are analyzed.

KEY WORDS: bolts; design; fasteners; loading, shock

(22)

Pickel, W. F.
TIGHTENING CHARACTERISTICS OF NUT AND STUD ASSEMBLIES, Product Engineering, January 1949, (Also appeared in Fasteners, Vol. 6, No. 1, 1949, pp. 10-13).

The consistent tightening of bolts and nuts is dependent upon thread surface, lubricant, material of the rubbing surfaces, and conditions of the nut face. Tests are described that measure the effect of the above parameters on the tightening characteristics of nut and bolt assemblies. A series of good torque application practices are presented and equations for computing the total stress involved are derived. Among the torque application practices suggested are: (1) bolts may be tightened in tension to 75% of the yield strength, (2) nuts should apply a tension load to the bolt equal or greater than the external load to be supported in service, (3) minimum thickness of thread plating provides best results, (4) minimum clearance between bolt and hole gives best results.

KEY WORDS: assemblies; bolts; bolting: characteristics; joints

(23)

Lenzen, K. H.
THE EFFECT OF VARIOUS FASTENERS ON THE FATIGUE STRENGTH OF A STRUCTURAL JOINT, AREA Bulletin No. 480, June-July 1949. (Reprinted in Proceedings, AREA, Vol. 51, 1950, pp. 1-28, and Summarized in BOLTED JOINTS UNDER FATIGUE LOADS, Fasteners, Vol. 6, No. 1, 1949, pp. 6-9).

The results of fatigue tests on joints fabricated with high tensile (1038 steel) quenched and tempered bolts are presented. Thirteen fatigue tests were conducted under full reversal of load. In the static tension test, tension was applied until the joint slipped. The investigation shows that bolted connections exhibit extremely high fatigue strength. Furthermore, the study indicates that the fatigue life is increased by high bolt clamping forces which introduce compressive stresses that overcome the tensile stress concentrations at the edges of the bolt holes. Carbonized washers also increase fatigue life by maximizing clamping force.

KEY WORDS: bolts; fatigue; static test; steel; testing

(24)

Wyly, L. T., Scott M. B. McCammon, L. B., and Lindner, C. W.
A STUDY OF THE BEHAVIOR OF FLOORBEAM HANGARS, Bulletin 482, AREA, Chicago, September-October 1949. (Also appeared in Proceedings, AREA, Vol. 51, 1950, pp. 51-73).

The report is basically a field study of the floorbeam hangers of the Illinois Central Railroad Bridge at Galena, Illinois. The particular object of the study, a form of hanger section consisting of two channels connected by occasional tie plates, was found to be a poor structural member because of excessive bending and uneven transfer of load from the floor beam. This uneven transfer of load should concern the designer (or detailer of gusset plates).

KEY WORDS: gussett plate; hangers, floor beam; stress concentration

(25)

Hechtman, R. A.
CONDITIONS AFFECTING THE SLIP OF STRUCTURAL STEEL BOLTED JOINTS, The Trend in Engineering, University of Washington, Vol. 1, No. 4, October 1949, pp. 12-18.

The slip in several types of bolted joints under load and the conditions which affect this slip are investigated and reported. The specimens consisted of double lap bolted joints made from plain-carbon structural steel plate. The bolts were rough forged from high strength structural steel. In one series of tests the bolt hole clearance was increased while the bolt tension was kept constant. The test results indicate that a reduction of the clearance in bolt holes is much more effective in decreasing the amount of slip than an increase in the bolt tension.

KEY WORDS: bolts; clearance, bolt hole; joint; slippage; tension

(26)

Kovac, J. J.
PRELOADING INTERNAL WRENCHING BOLTS, Fasteners, Vol. 6, No. 2, 1949, pp. 10-12.

Experimental tests were conducted on NAS bolts to determine the relationship between bolt preload and torque. Bolts of the following sizes were tested: 3/8 in., 7/16 in., 1/2 in., 9/16 in., 5/8 in., and 3/4 in. Twelve bolts, two of each size, were tested with lubricated threads, while twelve more bolts, two of each size, were tested without lubricant. Eighteen bolts, three of each size, were tested with an ANC-147 anti-seize compound under the bolt head as well as on the threads. The completely lubricated bolt showed a considerable increase in efficiency for all six sizes. It was found that the loss in efficiency from friction at the bearing surface under the bolt head was more severe than from friction developed in the threads.

KEY WORDS: bolts; fasteners; lubricants; pretensioning

(27)

Wyly, L. T.
SYMPOSIUM ON HIGH-STRENGTH BOLTS, Part I, Proceedings, AISC, April 12, 1950, pp. 22-27.

Presented is a study of structural members under repeated loading. The study was composed of a fact-finding survey of failures and an analysis of the failures, a study of stress distribution measurements in bridge hangers obtained in the field, and a study of stress distribution measurements in components of hangers obtained under controlled conditions. The author concludes that the bearing of rivets at the tops of rivet holes is the principle source of the high stress or strain concentrations which result in the low fatigue strength of hangers. These concentrations occur chiefly when rivets have lost, or never had, clamping force. A method of decreasing these concentrations is presented. Fatigue tests of bolted joints are explained. It was determined that superior fatigue performance may be achieved through the use of bolts, which have greater clamping force than rivets.

KEY WORDS: bolts; fatigue; force, clamping; hangers

(28)

Ruble, E. J.
SYMPOSIUM ON HIGH-STRENGTH BOLTS, Part II, Proceedings, AISC, April 12, 1950, pp. 27-31.

An investigation was made of the relative effects of various fasteners on the fatigue strength of three groups of structural joint, identical except for the type of fastener. The three types of fasteners were hot driven rivets, cold driven rivets, and high-strength bolts. The plates, made of A7 steel, were joined by nine 3/4 inch fasteners in a square pattern. A total of twenty-four joints were fabricated and tested in fatigue under a complete reversal of load. The fatigue strength of the joints fabricated with high-strength bolts was appreciably greater than that of the riveted joints. The conclusions based on laboratory tests were supported by examinations of railroad bridges in which it was noted that bolts remained tight longer than rivets in structures subjected to vibrational loads.

KEY WORDS: bolts; fatigue; rivet; testing

(29)

Stewart, W. C.
SYMPOSIUM ON HIGH-STRENGTH BOLTS, Part III, Proceedings, AISC, April 12, 1950, pp. 31-36.

A brief history of the Research Council is presented along with an explanation of its organization and projects. An extensive summary of the properties and behavior of high-strength bolts found through the research sponsored by the RCRBSJ is also presented. The possible future uses of high-strength bolts are discussed. High-strength bolts will be used in some cases for economy, while engineering requirements will dictate their use in others. They may be used as fitting-up bolts prior to riveting, as structural fasteners in field construction, and in cases where fatigue causes high rivet maintainence costs. The ASTM specifications are explained; and the recommended bolt, nut, and washer styles are described. It is pointed out that future research will probably result in new rules taking advantage of the properties of high-strength bolts.

KEY WORDS: bolts; pretensioning; properties; RCRBSJ; specifications

(30)

Munse W. H., Schutz, F. W., Jr., and Cox, H. L.
STATIC AND FATIGUE TESTS OF BOLTED STRUCTURAL LAP JOINTS, SRS No. 3, Dept. of Civil Engineering, University of Illinois, Urbana, July 1950.

Data from 35 tests was used in a detailed study of the fatigue strength of a two-bolt lap joint connected with high-strength structural steel bolts. The joints were tested on either zero-to-tension or a full reversal stress cycle. It is concluded that the amount of flexibility and side-sway in a lap joint have a predominant effect on the fatigue strength of the joint. When the slip per cycle is a few thousandths of an inch there is no danger of bolt failure from fatigue. The bolted joints usually fail through the gross section of the plates. It should be noted that static load-slip tests were conducted on 22 of the test specimens prior to the fatigue tests by applying a tension load in the fatigue machine.

KEY WORDS: bolts; fatigue; lap joint; slippage; static test

(31)

Wilson, W. M.
HIGH-STRENGTH BOLTS AS A MEANS OF FABRICATING STEEL STRUCTURES, Proceedings, Highway Research Board 1951, pp. 136-143.

The advantages of using high-strength bolts as structural fasteners instead of rivets are enumerated. After an analysis which included rationalization, laboratory testing, and the study of structures in service, it is concluded that for structural joints subjected to repeated loads, joints properly fabricated with high-strength bolts are superior to those using carbon-steel rivets.

KEY WORDS: bolts; force, clamping; tension; rivet

(32)

AREA Committee on Iron and Steel Structures
USE OF HIGH STRENGTH STRUCTURAL BOLTS IN STEEL RAILWAY BRIDGES, Proceedings, AREA, Vol. 51, March 1950, pp. 506-540. (Summarized by E. J. Ruble, Fasteners, Vol. 6, No. 4, 1950, pp. 3-5.

In 1948 and 1949, the research staff of the AAR installed over 1,000 high strength bolts of various sizes and lengths in about 20 different types of joints on twelve different bridges. In most cases, the installations were made where vibration of the members had made it difficult to keep rivets tight. An account of the installation and inspection of these bolts is presented. A check with a torque wrench on the tightness of a representative number of bolts revealed that the majority of the bolts retained their original clamping force. Some of the bolts appeared to have lost some of their clamping force, but it was not known whether the bolts were not properly tightened when installed or whether the bolted members were reseating themselves. It was definitely found that high-strength bolts, properly installed, stayed tight longer than rivets in similar joints subjected to the same vibrational loads.

KEY WORDS: bolts; installing; inspection; testing

(33)

RCRBSJ
PROGRESS REPORT OF RESEARCH COUNCIL ON RIVETED AND BOLTED STRUCTURAL JOINTS, Proceedings, AREA, Vol. 51, 1950, pp. 74-86. (Also appeared in Bulletin 482, AREA, September-October 1949; Summarized by H. H. Lind, COOPERATIVE RESEARCH, Fasteners, Vol. 6, No. 3, 1950, pp. 8-9).

The membership, projects, aims, and activities of the Research Council on Riveted and Bolted Structural Joints, formed in 1947, are explained. The Council is made up of fifteen sponsors composed of private industries and educational institutions. At the time of writing, seven projects were being investigated. A short status report of each project is given. Following are the projects which are in progress: I-Effect of Bearing Pressure on Static and Fatigue Strength of Riveted Joints; II-Effect of Rivet Pattern on Static Strength of Structural Joints; III-The Strength of Rivets in Shear and Combined Shear and Tension; IV-Fatigue Strength of Bolted Structural Joints; V-The Effect of Grip upon the Fatigue Strength of Riveted and Bolted Joints; VI-The Fatigue Strength of High Strength Steel Riveted Joints; and VII-Effect of Rivet Pattern on the Fatigue Strength of Structural Joints.

KEY WORDS: bolts; joints; projects; RCRBSJ; research; rivets

(34)

Milliken, M. P.
HOW TIGHT IS TOO TIGHT? Fasteners, Vol. 6, No. 1, 1950, pp. 14-17.

Bolt stresses were investigated theoretically and experimentally to determine the effect of external or structural loads on bolt load. Three different positions of load application were considered theoretically. In each case after the bolted members have separated, the total bolt load equals the external load. Good agreement was found between the theory and experiments of the usual case. In addition to the analysis of the stresses involved in tightening, a determination of the optimum tightening or preload is presented for several different materials, steel, aluminum, and magnesium.

KEY WORDS: assemblies; bolts; bolting

(35)

Harvey, C. L.
HIGH STRENGTH STEEL BOLTS, Fasteners, Vol. 6, No. 3, 1950, pp. 10-12.

ASTM Designation A325-49T, titled "Quenched and Tempered Steel Bolts and Studs with Suitable Nuts and Plain Washers", is discussed. This specification differs somewhat from many ASTM specifications in that it covers the performance of a finished product, bolts, and limits raw material and production processes only in a general manner. The methods of testing the full size bolt are discussed along with certain restrictions on the method of heat treatment. A table of the mechanical properties of high strength steel bolts is also presented.

KEY WORDS: bolts; fasteners; steel

(36)

Pinkel, R. H.
DETERMINING BOLT LOAD ELONGATION CURVES, Fasteners, Vol. 6, No. 4, 1950, pp. 8-9.

An extensometer designed specifically for bolts and a testing method to determine bolt load elongation curves are described.

KEY WORDS: bolts; mechanical properties; testing

(37)

Merritt, F. S.
UN SECRETARIAT USED UNUSUALLY LARGE RIVETS, Fasteners, Vol. 6, No. 4, 1950, pp. 12-14.

The use of extra large rivets in the construction of the United Nations Secretariat is described. Due to the design of the building (the height-width ratio is about 7 to 1) the builder was faced with unusual fabrication and erection problems. Heavy connections had to be designed to transmit high wind stresses from the girders to the columns. Rivets 1-1/4 in. in diameter were used because the use of smaller rivets would have been uneconomical or impossible. Rivets up to 8 inches in length were used for column connections because of the great thickness of the steel. Other design and erection problems and their solutions are also explained.

KEY WORDS: joints; rivets ; structural engineering

(38)

Wyly, L. T., and Carter, J. W.
STRESSES NEAR BOLT AND RIVET HOLES, Fasteners, Vol. 6, No. 4, 1950, pp. 15-17.

The effect of fastener clamping force and fastener bearing at the top of a hole on stresses around the hole is analyzed. The author shows that clamping force reduces the high tensile stress at the sides of the hole caused by the axial forces and also that bearing at the top of the hole causes stress 5.3 times as great as the average stress on the gross section. It is also reported that twisting and bearing caused by slip in a single lap joint increases the strain at the sides of the hole. The stresses due to strain concentrations at rivet and bolt holes are analyzed by photo-elastic techniques. Suggestions are made to overcome the effects of the holes.

KEY WORDS: bolts; force, clamping; joints; rivets; stresses

(39)

Lappo, T.
EXTRA FLANGE RIVETS FOR WEB SPLICE EASILY COMPUTED, Civil Engineering, Vol. 20, 1950, p. 786.

Presented is a method for computing the pitch of the additional rivets required on the abutment side of a web splice of a girder designed for the full strength of the web in bending. Plates must be furnished in each flange to carry the web moment and additional rivets are needed to supplement those required for shear. The method is illustrated by two examples.

KEY WORDS: design; joint, web; rivets

(40)

Wright, D. T., and Munse, W. H.
CALIBRATION TESTS OF HIGH STRENGTH BOLTS, Dept. of Civil Engineering, University of Illinois, SRS No. 9, January 1951.

A series of 38 tests was made on 0.4%C quenched and tempered high-strength steel bolts (A325, A.S.A. Spec. B18.2) to determine the relationships of bolt elongation and torque to bolt load. The bolts were calibrated by either a torque-tension test, a static tension test or a combination of these tests. The results are presented graphically. Reducing the effective area of a bolt by such means as fully threading the shank was found to increase the overall elongation of the bolt for a given load and to reduce the elastic limit and ultimate capacity. It was also shown that lubricating the nut was as effective as lubricating both the bolt and nut in reducing the required torque for a given load.

KEY WORDS: bolts; nuts; tensile strength

(41)

Becker, W. K., Sinnamon, G. K., and Munse, W. H.
THE EFFECT OF BEARING PRESSURE ON THE STATIC STRENGTH OF RIVETED JOINTS, Dept. of Civil Engineering, University of Illinois, SRS No. 8, January 1951.

The effect of high rivet bearing on the static strength and behavior of riveted joints is reported. The 32 specimens tested consisted of double strap butt joints with plates connected by five rivets. A constant ratio of rivet shear stress to plate tensile stress in the middle plate was maintained in all joints by varying the thickness and width of the butt plate. It was found that although the ultimate loads for companion specimens were in excellent agreement the test efficiencies were appreciably lower than their theoretical efficiencies. The rivet size had no noticable influence on the static strength and a variation in the bearing ratio from 1.3 to 3.0 had little influence on the joint strength.

KEY WORDS: bearing; joints; rivet; slippage; strength, static

(42)

Young, D. R., and Hechtman, R. A.
SLIP OF STRUCTURAL STEEL DOUBLE-LAP JOINTS ASSEMBLED WITH HIGH-STRENGTH BOLTS, The Trend in Engineering, Part I in April 1951, pp. 24-27, and Part II in July 1951, pp. 23-26.

The report is divided into two parts - Part I, The Effect of Bolt Tension and Faying Area Upon Slip and Part II, The Effect of Surface Condition of Faying Area Upon Slip. Part I describes twenty-three tests of plain-carbon structural steel double-lap joints assembled with high strength bolts. All of the joints had mill-scale faying areas. Eighteen joints were tested in Part II. Part II reports the effect of other surface conditions of the faying areas upon the slip of the joint, such as mill-scale finish with drilled holes, mill-scale finish with subpunched and reamed holes, red-lead paint, varnish, and sandblasted finish. The results showed that coatings should not be used on faying surfaces of a joint if prevention of slip is a criterion of design.

KEY WORDS: area, faying; bolts, high strength; joint; slippage

(43)

Higgins, T. R.
BOLTED JOINTS FOUND BETTER UNDER FATIGUE, Engineering News Record, Vol. 147, August 2, 1951, pp. 35-36.

The advantages of using high-tensile steel bolts in place of rivets for structures subjected to widely fluctuating dynamic loading are discussed. Lower installation costs, less noise, and slip-free joints are the primary advantages. Bolt characteristics and clamping force are briefly discussed.

KEY WORDS: bolts; costs; fatigue; force, clamping

(44)

Redshaw, S. C.
THE DESIGN CHARACTERISTICS OF ALUMINUM RIVETED JOINTS, Sumposium on Welding and Riveting Larger Aluminum Structures, London, November 1951, pp. 155-175. (Discussed in JOINT DISCUSSION ON RIVETING, by J. G. Whitman, J. M. Smith, J. M. Murray, et al., Symposium on Welding and Riveting Larger Aluminum Structures, London, November 1951, pp. 176-219.

The various factors influencing the design of aluminum alloy riveted joints are discussed, including the effect of different types of joint materials, and the fatigue resistance of the joint. The authors find that it is sufficiently accurate to assume that load is equally distributed among the rivets. It is recommended that for joint design the rivet alloy should be ductile and the plate alloy should have a sufficiently high ratio of proof to ultimate stress. It is further suggested that the length of the joint and rivet pitches should be as small as practicable and that the rivet diameter-plate thickness ratio should be such that the rivet has as high a ductility as possible.

KEY WORDS: aluminum; efficiency; fatigue; joint; rivet; shear stress

(45)

Bailey, J. C.
THE PROPERTIES AND DRIVING OF LARGE ALUMINUM ALLOY RIVETS, Symposium on Welding and Riveting Larger Aluminum Structures, London, November 1951, pp. 133-154. (Discussed in JOINT DISCUSSION ON RIVETING, by J. G. Whitman, F. J. Walker, J. M. Murray, W. Muckle, et al., Symposium on Welding and Riveting Larger Aluminum Structures, London, November 1951, pp. 176-219).

The progress made since 1946 in the development of aluminum alloy rivets larger than 3/8" diameter is outlined. Fabrication of a joint by Aluminum alloy rivets up to 7/8" diameter is said to be practical. Data on the closing pressures for cold squeeze riveting is presented. Ultimate shear stress values for hammer driven and squeeze driven rivets, maximum rivet sizes for pneumatic driving with various points, and shear strengths of cold driven rivets are also presented. Pneumatic hammer riveting, rivet points of reduced sizes and the factors influencing the rivet shear strength are discussed.

KEY WORDS: aluminum; clearance; joint; rivet; riveting, cold

(46)

Delaney, T. J.
COLD RIVETING USED IN FIRST ALL-ALUMINUM HIGHWAY BRIDGE, Fasteners, Vol. 7, No. 2, 1951, pp. 5-6.

The use of Alcan 16 S-T alloy cold driven rivets in the Arvida Bridge, Quebec, Canada is reported. The use of a new cold driving technique, utilizing a pneumatic gun usually used for hot driven steel rivets, is explained. The rivet gun with a conventional pan and flat head repeatedly slipped off the rivet head, producing misshapen and non-concentric heads, and damaging the surrounding plate material. Extensive research and testing resulted in the design of the annular head rivet, a new type of rivet. The annular head facilitates the spread of the metal to form the head and helps to prevent the gun from slipping off during the driving.

KEY WORDS: aluminum; head; rivet; riveting, cold

(47)

Ruble, E. J.
STRUCTURAL DESIGNERS ACCEPT HIGH STRENGTH BOLTS, Fasteners, Vol .7, No. 2, 1951 pp. 7-10.

The Research Council on Riveted and Bolted Structures, organized in 1947, recognized that the existing practice in the design of riveted and bolted structures was developed empirically from experience and that many of the practices were not supported by definite experimental data. The council's aims and the plans of its research program are presented along with lists of the sponsors, representatives, and members-at-large. Recommended also are specifications for bolts, nuts, washers, bolted parts, assembly, and inspection.

KEY WORDS: bolts; nuts; RCRBSJ; specification; washers

(48)

Hartman, E. C., Holt, M., and Eaton, I. D.
STATIC AND FATIGUE STRENGTHS OF HIGH-STRENGTH ALUMINUM ALLOY BOLTED JOINTS, NACA TN 2276, Washington, February 1951.

Results are reported of static and fatigue tests on several types of joints fabricated from 75S-T6, 24S-T4, and 14S-T6 high strength aluminum-alloy extruded bar. All the specimens had the same net-section area. In the static tensile tests, the 75S-T6 double-shear joint withstood the highest ultimate load and the 75S-T6 clamped-keyed joint the lowest. Of all the joints studied, the 75S-T6 double-scarf joint had the highest fatigue strength. It was also found that when the critical net-area was held constant, other design details had a greater effect in prolonging fatigue life than did a change in materials within the group studied. There was no apparent correlation between the static and fatigue strengths of the joints studied.

KEY WORDS: bolts; bolted joints; fatigue life

(49)

Fasteners
MORE THAN A MILLION POUNDS OF FASTENERS, Fasteners, Vol. 7, No. 1, 1951, pp. 5-6.

A description of the 525 William Penn Place building in Pittsburgh Pa., and how it was erected is presented. More than 500 tons of bolts and rivets were used in constructing the building. Eighty-five thousand field bolts were used at the construction site, and 660,000 rivets were driven in the shop and at the site. Architectural and erection specifics are also presented.

KEY WORDS: construction; fasteners ; structural engineering

(50)

Massard, J. M., Sinnamon, G. K., and Munse, W. H.
THE EFFECT OF BEARING PRESSURE ON THE STATIC STRENGTH OF RIVETED JOINTS, Dept. of Civil Engineering, University of Illinois, SRS No. 21, January 1952.

The effect of high rivet bearing pressure on the static strength and behavior of double strap butt-type joints designed to fail in the outer plates is investigated. Tests of thirty-three riveted specimens are described. It is concluded that the strength of the joint as a whole is not affected by a variation in the bearing ratio while the strength of the net section of the joint varies with the bearing ratio.

KEY WORDS: bearing; joints; rivet; strength, static

(51)

Fisher, W. A. P., Cross, R. H., and Norris, G. M.
PRE-TENSIONING FOR PREVENTING FATIGUE FAILURE IN BOLTS, Aircraft Engineering, England, Vol. XXIV, No. 280, June 1952, pp. 160-163.

The prevention of fatigue in bolts by controlled pre-tensioning is investigated theoretically. It is shown that pre-tensioning reduces the alternating load in the bolt and that the fitting stiffness plays an important part in this reduction. Fatigue tests on 3/4 inch B.S.F. bolts with various amounts of pre-tension show how this reduction in alternating load can prevent fatigue failure. Unless pre-tensioning will be maintained in service, its benefits should not be relied upon.

KEY WORDS: bolts; fatigue; pre-tensioning

(52)

Wright, D. T., and Munse W. H.
STATIC TESTS OF BOLTED AND RIVETED JOINTS, Dept. of Civil Engineering, University of Illinois, SRS No. 20, January 1952. (Summarized in LABORATORY TESTS OF BOLTED JOINTS, by W. H. Munse, D. T. Wright, and N. M. Newmark, Transactions, ASCE, Vol. 120, Paper No. 2778, 1955, pp. 1299-1318).

Static loading tests of 38 high-tensile bolted lap-type joints are discussed. Twelve tests of riveted joints are reported for comparison. For joints with 7/8 in. bolts, an end distance of 1-1/2 in. is sufficient to prevent end tearing. Two-fastener lap joints have greater ultimate tensile strength than three-fastener lap joints or two-fastener butt joints. The faying surface condition, the fastener type, and the bolt tension are the primary factors affecting the load-slip relations while joint type and shear ratio are secondary. Bolt tension and faying surface condition had no appreciable effect on the ultimate strength of either riveted or bolted joints. Bolted joints with a shear ratio of 0.75 failed in tension, while those with ratios of 1.0 and 1.25 failed in shear. On the basis of these results, the authors recommend a shear ratio of 1.25.

KEY WORDS: bolts; lap joint; ratio, shear; rivet; static test; surface, faying; tension

(53)

Whitmore, R. E.
EXPERIMENTAL INVESTIGATION OF STRESSES IN GUSSET PLATES, Bulletin No. 16, Engineering Experiment Station, University of Tennessee, Knoxville, May 1952.

Tests were made on 61-ST high-strength aluminum alloy, bakelite, and masonite joints to determine the stress distribution in certain types of gusset plates, including the maximum intensity of stress and its location, and to devise for use in structural design a simple method of approximating the maximum stresses. The test joints were designed as L_2 joints of a Warren truss. Edge stresses were lower than expected and the straight-line distribution of stress customarily assumed in analyzing such plates was found to be incorrect.

KEY WORDS: gusset plates; joint; stress concentration; truss

(54)

Wilson, W. M., Munse, W. H. and Cayci, M. A.
A STUDY OF THE PRACTICAL EFFICIENCY UNDER STATIC LOADING OF RIVETED JOINTS CONNECTING PLATES, Bulletin No. 402, Engineering Experiment Station, University of Illinois, July 1952. (First distributed as THE EFFECT OF THE RIVET PATTERN ON STATIC STRENGTH OF RIVETED JOINTS CONNECTING PLATES, by Wilson, Munse, and Cayci, Dept. of Civil Engineering, University of Illinois, Progress Report-Project II, January 1950).

Discussion is presented of tests of 38 large riveted lap and double strap butt joints made with 1/2 or 3/4 in. plates and 3/4 or 7/8 in. rivets. The tests were concerned with static strength as well as the effect of temperature on strength and fracture. A comparison is made of the strengths of joints with various rivet patterns. Test efficiencies were 75-85%. It is concluded that an increase in the traverse distance between rivets in the outer row to more than 4-1/2 in. does not assure increased joint efficiency.

KEY WORDS: butt joints; efficiency; rivets; steel; testing

(55)

Schutz, F. W., and Newmark, N. M.
THE EFFICIENCY OF RIVETED STRUCTURAL JOINTS, Dept. of Civil Engineering, University of Illinois, SRS No. 30, September 1952. (Summarized as EFFECTIVE NET SECTION OF RIVETED JOINTS, by F. W. Schutz, Proceedings, 2nd Illinois Structural Engineering Conference, November 1952, pp. 54-62).

The development of the relative gage method for predicting joint efficiency, the effect of various fastener patterns on the static strength of double strap butt type riveted and bolted joints, and the variables other than fastener pattern influencing the static strength are presented. Tests show that fastener tension, mechanical properties of fastener material, and longitudinal spacing of transverse rows of fasteners have no great effect on the joint efficiency. However, staggering alternate fasteners in the first transverse row increases the joint efficiency, as does an increase in transverse spacing of longitudinal lines of fasteners. The joint efficiency is independent of the number of transverse rows and the number of longitudinal lines of fasteners.

KEY WORDS: bolts; ductility; efficiency; joint; measurement; pitch; rivet

(56)

Stewart, W. C.
STRUCTURAL JOINTS WITH HIGH-STRENGTH BOLTS, Proceedings, The Second Illinois Structural Engineering Conference, University of Illinois, Urbana, November 1952.

The advantages of high-strength bolts over rivets are listed. High-strength bolts have higher shear strength and clamping force than rivets. Joints connected with high-strength bolts have greater fatigue strength than riveted joints when the high strength bolt are tightened to high preload levels. Because high-strength bolts are unaffected by external tension, they may be used in moment-resisting connections. The author thinks high strength bolts are practical and that their cost is competitive with other types of fasteners.

KEY WORDS: bolts; joints; rivets

(57)

Baron, F., and Larson, E. W., Jr.
THE EFFECT OF GRIP ON THE FATIGUE STRENGTH OF RIVETED AND BOLTED JOINTS, Bulletin No. 503, AREA, 1952. (First appeared as Research Report C110, The Technological Institute, Northwestern University, Evanston, Illinois, September-October 1952).

The effect of clamping force and length of grip on the fatigue strength of riveted and bolted structural joints is investigated. The specimens consisted of double butt joints having a tension-shear-bearing ratio of about 1.00:0.75:1.50. Forty-six bolted joints and forty-six hot-driven riveted joints were tested in fatigue. In addition, sixteen fatigue tests on cold-formed cold-driven riveted joints and forty fatigue tests on hot-formed cold-driven riveted joints were conducted. Also, static tension tests were conducted on three bolted joints, three hot-driven riveted joints, six cold-formed cold-driven riveted joints and twelve hot-formed hot-driven riveted joints. Static and fatigue tests show that the fatigue strength of a joint increases with an increase in fastener clamping force. Bolted joints are stronger in fatigue than riveted joints. The fatigue strength of a hot-driven rivet joint is greater than cold-driven rivet joint. Cold-driven rivets produce too little clamping force and hole filling to prevent joint slippage. Bolts and rivets produce identical plate efficiences.

KEY WORDS: bolts; clamping; efficiency; fatigue; force; joint; rivet; slippage

(58)

Higgins, T. R., and Munse, W. H.
HOW MUCH COMBINED STRESS CAN A RIVET TAKE? Engineering News Record, December 4, 1952, Vol. 149, No. 23, pp. 40-42. (Distributed as SRS No. 45, Dept. of Civil Engineering, University of Illinois, 1952).

Tests are summarized which were carried out in the Structural Research Laboratory of the Department of Civil Engineering at the University of Illinois to determine how much combined stress a rivet can take so that a revision of the design specifications for tension and shear in rivets may be studied. The test results indicate that an increase in grip produces a reduction in ultimate strength. The rivet diameter has little effect on the stress at failure. In shear, machine driven rivets are slightly weaker than hand-pneumatic driven rivets. The method of rivet manufacture has no effect on the ultimate strength. The tension to shear ratio determined from the tests of 103 rivets conforms with the 1946 revision of the AISC Specifications (20/15=1.333). An elliptical and a linear equation are suggested for computing allowable shear stress.

KEY WORDS: ratio, tension-shear; rivet; shear stress; tension

(59)

Feldhausen, G. J., Jr.
DO SEMI-RIGID CONNECTIONS PROVE ECONOMICAL?, Fasteners, Vol. 8, No. 1, 1953, pp. 7-10.

The economic advantages of semi-rigid connections are presented. Examples are given in which designing beams with semi-rigid connections instead of simple spans resulted in savings in steel tonnage and cost. Other advantages of this type of design are: (1) reduced deflection of the beam when the ends are restrained; (2) when lateral buckling of the beam is critical a shorter span length can be used in the allowable bending stress formula; and (3) the bending moment has no appreciable effect on the column.

KEY WORDS: economics; joints, semi-rigid; spans

(60)

Fasteners
BOLTS SPEED ERECTION, Fasteners, Vol. 8, No. 1, 1952, pp. 12-13.

Presented is a description of the demolition of the old Superior Foundry, Inc. facility at Cleveland, Ohio and the construction of the new foundry. It is estimated that bolting of field connections took less than half the time that other methods would have required. "When the job calls for speed and economy, the steel contractor calls for bolts".

KEY WORDS: bolting; economy

(61)

Engineering News Record
HERE'S A BETTER WAY TO DESIGN SPLICES, Engineering News Record, Vol. 150, Part I, January 8, 1953, pp. 41-42.

The "relative gage method", for predicting joint efficiency is explained. The formula is developed from the results of 1130 tension failure tests. The joints studied are riveted or bolted, lap and butt type and are made from a wide variety of materials including wrought iron, structural steel, and various aluminum alloys. This article is a synopsis of a thesis by F. W. Schutz (see abstract 56).

KEY WORDS: bolts; design; efficiency; joint; measurement; rivet

(62)

Fuller, James R., and Munse, W. H.
LABORATORY TESTS OF STRUCTURAL JOINTS WITH OVER-STRESSED HIGH TENSILE STEEL BOLTS, Dept. of Civil Engineering, University of Illinois, SRS No. 44, January 1953.

The results of static and repeated load tests conducted on seven double-strap butt-type joints fastened with high tensile steel bolts are summarized. The bolts were torqued far into their inelastic range. It is found that the static strength of the joints is not affected by the overstressing of the bolts and that the overstressed bolts are not likely to fail in fatigue.

KEY WORDS: bolts; fatigue; loads

(63)

Francis, A. J.
THE BEHAVIOR OF ALUMINUM ALLOY RIVETED JOINTS, Research Report No. 15, The Aluminum Development Association, London, March 1953.

The behavior of aluminum alloy riveted double shear joints under axial and eccentric static loading was determined through extensive experimentation. Also presented is a theoretical solution for the load partition and ultimate strength of joints. It is applicable to both the elastic and inelastic ranges. The solution is achieved through a semi-graphical solution based on control tests of the component parts.

KEY WORDS: aluminum; rivet; shear stress

(64)

Research Council on Riveted and Bolted Structural Joints
NEW CONCEPTS IN STRUCTURAL JOINT DESIGN, Second Progress Report on Research Council on Riveted and Bolted Structural Joints, Distributed by the Engineering Foundation, December 1953.

This report briefly outlines the accomplishments of the Research Council on Riveted and Bolted Structural Joints and the status of the council's current projects listed below:

Project 1: "The Effect of Bearing Pressure on the Strength of Riveted Joints".

Project 2: "The Effect of Rivet Pattern on the Static Strength of Structural Joints".

Project 3: "The Strength of Rivets in Combined Shear and Tension".

Project 4: "Fatigue Strength of Bolted Structural Joints".

Project 5: "The Effect of Grip on the Fatigue Strength of Riveted and Bolted Joints".

Project 6: "Fatigue Strength of High-Strength Steel Riveted Joints".

Project 7: "The Effect of Rivet Pattern upon the Fatigue Strength of Structural Joints".

Project 8: "Fatigue Tests on Cumulative Damage in Structural Joints".

KEY WORDS: bearing; rivet; shear stress; tension; fatigue; slippage

(65)

AREA Committee on Iron and Steel Structures
USE OF HIGH-STRENGTH STRUCTURAL BOLTS IN STEEL RAILWAY BRIDGES, Proceedings, AREA, Vol. 54, 1953, pp. 929-940.

High-strength bolts were installed in 16 railroad bridges to determine if such bolts retain their clamping force in structural joints subjected to vibrational loads at various temperatures. Because these bolts were found to be superior to rivets in this application, recommendations are made for the revision of the Specification for Assembly of Structural Joints using High-Tensile Steel Bolts in Steel Railway Bridges.

KEY WORDS: bolts; joints; railroad bridges

(66)

Fasteners
HIGH STRENGTH BOLTING, Fasteners, Vol. 9, No. 1, Ohio, 1953, pp. 9-13.

The three distinct advantages of high strength bolts-adaptability, strength, and economy-and the basic principle of the application of high strength bolts-load transfer due to clamping force-are presented. Included is a brief presentation of the specifications, assembly, design, slip, painting of contact surfaces, bolt load, fatigue strength, and economics of the use of high tensile bolts.

KEY WORDS: bolts; design; economic factors

(67)

Baron, F., and Larson, E. W., Jr.
PROPERTIES AND BEHAVIOR OF A HIGH-STRENGTH RIVET STEEL, Proceedings, ASTM, Vol. 53, 1953, pp. 597-609.

The authors report on an investigation of a high-strength rivet steel which the Bethlehem Steel Co. has developed. The rivet steel has certain advantages over other steels meeting the requirements of ASTM specification A195-52T. This steel is as ductile and is driven as easily and quickly as ordinary carbon rivet steel. At short lengths of grip, the average clamping stresses of the high-strength steel rivets are about the same as those of carbon steel rivets. However, at grip lengths of 2 in. and greater, the average clamping stresses of the high-strength steel rivets are appreciably greater than those of carbon steel rivets. The behavior in static tension and in fatigue of butt joints fastened with rivets of this high-strength low-alloy steel was compared to that of joints fastened with rivets of ordinary carbon steel. The joint efficiencies for static loads and the fatigue strengths were about the same irrespective of the kind of rivet steel.

KEY WORDS: efficiency; properties; rivet; stress, clamping

(68)

Baron, F., and Larson, E. W., Jr.
STATIC AND FATIGUE PROPERTIES OF CARBON, SILICON, AND HIGH-STRENGTH LOW-ALLOY STEEL PLATES HAVING A HOLE, Proceedings, ASTM, Vol. 53, 1953, pp. 805-822.

Fifteen plate steels including 7 low-alloy steels, 4 silicon steels, 3 ordinary carbon steels, and 1 rimmed steel were investigated to determine fatigue strength, the relationship between fatigue strength and stress-strain characteristics. The fatigue strengths of the various steels increased with tensile strength and yield strength. Fatigue lives of the steels were more closely related to maximum stresses at the net sections.

KEY WORDS: fatigue strength; steel; tensile strength

(69)

Chang, F. K., and Johnston, B. G.
TORSION OF PLATE GIRDERS, Transactions, ASCE, Paper No. 2549, Vol. 118, 1953, pp. 337-382. (Also appeared in Proceedings, ASCE, Separate No. 125, April 1952).

Analytical and experimental research was undertaken to determine the stress distribution, stiffness, and strength of bolted, riveted, and welded plate girders under uniform twisting moment. Seventy-two tests were made on fifteen different specimens. Eleven of the specimens were finally tested into the plastic range. Test variables included the number of cover plates, the rivet pitch, variable tension in bolts, and girder cross-section, with or without stiffeners. Formulas are proposed for calculating rivet or bolt pitch and size of welds for the bolted, riveted, and welded plate girders. It was found that the maximum shear stress occurred in the fillet between flange and web, while the next highest stress occurred in the flange near the rivet (or bolt) head.

KEY WORDS: flange; plates, cover; pitch; rivet; shear stress

(70)

Laub, W. H., and Phillips, J. R.
THE EFFECT OF FASTENER MATERIAL AND FASTENER TENSION ON THE ALLOWABLE BEARING STRESSES OF STRUCTURAL JOINTS, Fritz Laboratory Report 243.2, Lehigh University, Bethlehem, Pennsylvania, June 1954.

This report summarizes the results of tests made on 22 double-strap butt joints. Five different T:S:B ratios (ratios of tensile, shear, and bearing stresses to tensile stresses) were studied. The effect of fastener material and initial fastener tension on allowable bearing stresses was studied. Generally speaking, high bearing-to-tension ratios (T:S:B=1:0.92:2.48) have little effect on the efficiencies of the high-tensile bolted connections. The authors conclude that it is possible to raise the balanced design ratio for both common and high-tensile bolts.

KEY WORDS: bolts; design; efficiency; joints; failure; tension test

(71)

Schenker, L., Salmon, C. G., and Johnston, B. G.
STRUCTURAL STEEL CONNECTIONS, University of Michigan, AFSWP Report No. 352, Project 2065-1-F, June 1954.

Chapter I reviews and evaluates the effect of a number of variables on the properties of rivets and bolts. The basic properties of rivet materials are important in determining the characteristics of the finished rivets. Machine driving produces greater rivet strength than pneumatic hammer driving. The ratio of ultimate shear strength to ultimate tensile strength does not vary far from 0.75. The rivet strength varies inversely with grip length. Driven rivets experience a reduction of energy absorbed per unit volume of rivets. Chapter II explains the load-deformation relationship, effect of rivet pattern on plate and rivet strength, and ultimate strength of bolted joints. Chapter III discusses continuous frame connections. Generally these connections are welded rather than riveted. Chapter IV discusses the behavior of flexible and semi-rigid beam-to-column connections. In particular riveted seat and top angle connections, riveted web clip angles, and riveted connections with structural tees are discussed. In Chapter V a theoretical analysis of the behavior of column anchorages is presented.

KEY WORDS: analyzing; bolts; design; joints; rivets; steel

(72)

Hartman, E. C., Holt, M., and Eaton, I. D.
ADDITIONAL STATIC AND FATIGUE TESTS OF HIGH-STRENGTH ALUMINUM ALLOY BOLTED JOINTS, NACA TN 3269, Washington, D. C., July 1954.

Tests were made in the Aluminum Research Laboratory to investigate the static and fatigue strengths of stepped double-shear bolted joints; and the effect of bolt clearance and static preload on fatigue strength of bolted joints. Also discussed is the feasibility of the penetrant inspection method for locating fatigue cracks. The influence of fatigue cracks on the static load-carrying capacity is discussed. The stepped double-shear joint withstood fewer fatigue cycles than either the plain double-shear joint or double-scarf joint but its fatigue life exceeded that of all other joint designs tested. Bolt-hole clearance had no significant effect on the fatigue life of plain scarf joints. However, preloading bolts in tension to half way between the yield and ultimate strengths increased the fatigue life of plain scarf joints by 5.9 to 1. The same preloading increased the fatigue life of double-shear joints by 1.4 to 1.

KEY WORDS: aluminum; bolts; fatigue; joints; static test; testing

(73)

Leahey, T. F., and Munse, W. H.
STATIC AND FATIGUE TESTS OF RIVETS AND HIGH-STRENGTH BOLTS IN DIRECT TENSION, Dept. of Civil Engineering, University of Illinois, SRS, No. 80, July 1954.

The effects of initial bolt tension, applied load, bolt spacing parallel to web, and the non-parallel surfaces between the heads of the bolts and the joined members on the behavior of high strength bolts in direct tension are determined is compared with that of similar riveted connections. The static and fatigue behavior of high-strength bolted connections. Five static and eighteen fatigue tests were conducted on specimens consisting of two short sections of a 24 I 100 beam fastened with high strength bolts, and one static and three fatigue tests for comparison were conducted on similar specimens fastened with 3/4 in. rivets. The study shows that prestress in the bolts has a marked effect on their fatigue strength. The fatigue life of the bolts increased as prestress was increased. Bolts prestressed to 0.9 of proof load and subjected to a stress range from 0 to 0.47 of proof load did not fail during 2,000,000 cycles. The ultimate static strength of the bolts was independent of prestress. Also, the ultimate strength was adversely influenced by the prying action of the flanges.

KEY WORDS: bolts; fatigue strength; joints; prestressing; rivets; tension

(74)

Carter, J. W., McCalley, J. C., and Wyly, L. T.
COMPARATIVE TEST OF A STRUCTURAL JOINT CONNECTED WITH HIGH-STRENGTH BOLTS AND A STRUCTURAL JOINT CONNECTED WITH RIVETS AND HIGH-STRENGTH BOLTS, Bulletin 517, AREA, September-October 1954. (Also appeared in Proceedings, AREA, Vol. 56, 1955, pp. 217-268).

This is a report of the behavior under static load of two full scale joints which represented the connections of a floor beam hanger to upper chord gussets of a railway bridge. One joint was riveted and the other was fastened with high-strength bolts. The results demonstrate that both rivets and high strength bolts work satisfactorily, in structural joints. However, if rivets are replaced with high-strength bolts, the high local stresses and strains at the sides of the holes are eliminated. Therefore, bridges can be protected against fatigue failure by replacing the rivets at the edges of the gussets with high-strength bolts.

KEY WORDS: beam; gusset plate; joint; rivet; slippage

(75)

Fasteners
RESEARCH COUNCIL ANNOUNCES NEW SPECIFICATIONS FOR HIGH STRENGTH BOLTS, Fasteners, Vol. 9, No. 3, Ohio, 1954, pp. 10-12.

A brief history of the trend toward the extensive use of high-strength bolts is presented along with the Research Council's reasons for research in this area. In 1951 the Research Council, in order to control the increasing use of high strength bolts, issued "Specifications for the Assembly of Structural Joints Using High Tensile Steel Bolts". After the completion of more research, the Research Council presents, in this paper, a first revision to the original specification. Four major areas are changed and the changes discussed: The areas include washers, painting, assembly, and inspection. Also presented are the specifications approved February 27, 1954 by the Research Council on Riveted and Bolted Structural Joints.

KEY WORDS: bolts; nuts; specifications; washers

(76)

Delaney, T. J.
RIVETING CANADA'S ALUMINUM MINESWEEPERS, Fasteners, Vol. 9, No. 4, Industrial Fasteners Institute, Cleveland, Ohio, 1954, pp. 6-7.

The ease and speed with which the aluminum rivets (Alcan 55.S-T33 alloy) were cold driven into the Royal Canadian Navy's aluminum non-magnetic mine-sweepers are described. Fourteen of these vessels were constructed, each requiring 250,000 rivets. The ships commissioned in the Pacific and Atlantic, are entirely satisfactory.

KEY WORDS: aluminum; riveting, cold; rivets

(77)

Ringer, A. G.
PRINCIPLES AND USES OF IMPACT WRENCHING, Fasteners, Vol. 10, No. 3, 1954, pp. 3-5.

The principles and uses of impact wrenching are presented in this article. The impact wrench can be used safely in any position, and it comes in sizes to handle nuts on bolt sizes ranging from a #12 to a 7" diameter. Power may be supplied by electricity or compressed air. A cutaway view of the wrench assembly is shown and a description of procedure of operation follows. The impact wrench has been highly useful in the fastening of high-strength structural bolts. No special skill is required of the wrench operator, the torque may be varied by changing the driving force.

KEY WORDS: bolts; safety; torque; wrench, impact

(78)

Beam, W. S., and Munse, W. H.
EFFECTS OF REPEATED LOADINGS ON STRUCTURAL CONNECTIONS WITH HIGH STRENGTH BOLTS, Dept. of Civil Engineering, University of Illinois, SRS No. 91, January 1955.

Three groups of small truss-type specimens having a tension:shear ratio of 1.0:0.75 were fabricated using either bolts or rivets from 6-in. 12.5 lb. I-sections One specimen from each group was tested statically and the remaining four were tested in fatigue to determine the effects of repeated loadings on structural connections. It was found that, in general, the fatigue strengths of tension members with bolted connections and flexural members with bolted partial-length cover plates may be expected to be somewhat greater than that of similar riveted members.

KEY WORDS: bolts; fatigue strength; joint; loadings, repeated; rivet

(79)

Baron, F., Larson, E. W., Jr., and Kenworthy K. J.
THE EFFECT OF CERTAIN RIVET PATTERNS ON THE FATIGUE AND STATIC STRENGTH OF JOINTS, Published by the Research Council on Riveted and Bolted Structural Joints, Distributed by the Engineering Foundation, February 1955.

Presented are the effects of rivet patterns on the fatigue strength of structural steel joints, including the effect of varying the pitch between the rows of rivets; the effect of advancing certain rivets beyond the first row of rivets; and the effects of edge distance, gage distance, and certain rivet patterns. Fatigue lives of joints are not improved by either staggering the inner or outer rivets of the first row of rivets having a rectangular pattern or varying the pitch of 3/4 in. rivets from 2-1/4 in. to 6 in. Extreme values of edge or gage distance decrease the fatigue life. The fatigue lives cannot be predicted on the basis of static efficiencies. The static efficiencies of the various joints tended to increase with increases in values of g/d or 2e/d. The actual efficiencies of joints are closely related to theoretical efficiencies obtained by Schutz's rule and Wilson's rule than those obtained by other rules.

KEY WORDS: fatigue; joint; rivet; strength, static

(80)

Hechtman, R. A. Flint, T. R., and Koepsell, P. L.
FIFTH PROGRESS REPORT ON SLIP OF STRUCTURAL STEEL DOUBLE-LAP JOINTS ASSEMBLED WITH HIGH-TENSILE STEEL BOLTS, Dept. of Civil Engineering, University of Washington, Seattle, February 1955.

The fifth and final progress report on slip in double-lap joints is presented. Seven tests were made on joints with A325 bolts and having tension:shear ratios of 1.0:0.75, 1.0:0.73, and 1.0:0.78. Mill-scale-surface bolted joints loaded to design shear stress on the bolts slipped partly into bearing before slip stops. As the length of the joint increases, the two end rows carry an increasingly greater part of the load. It is imperative that static load be applied slowly enough to be really "static". Tests of small joints do not fully describe the action of large joints. Longer joints may be more critical than shorter joints in the cases of fatigue or brittle failure.

KEY WORDS: joint, double-lap; ratio, shear; slippage; tension

(81)

Fuller, J. R., Leahey, T. F., and Munse, W. H.
A STUDY OF THE BEHAVIOR OF LARGE I-SECTION CONNECTIONS, Proceedings, ASCE, Vol. 81, Sep. No. 659, April 1955. (Distributed by the Dept. of Civil Engineering, University of Illinois, as SRS No. 97, 1955. Appeared first as STATIC TENSILE TESTS OF I-SECTION CONNECTIONS, Dept. of Civil Engineering, University of Illinois, SRS No. 68, January 1954).

Three large structural truss-type I-section tension connections were tested. One was assembled with hot-driven rivets. The other two were assembled with high-strength bolts, one with hardened beveled washers against the sloping faces of the I-beam flanges. The remaining specimen was bolted using hardened flat washers so that the bolt shanks could bend as the bolts were tensioned. The joints with flat washers performed as well or better than those connected with beveled washers. The distribution of strains throughout the sections were not greatly affected by the type fastener and test efficiencies were approximately 10% less than the net section efficiency. The stress distribution across the critical section of the webs of the I-sections were analyzed in order to estimate the effectiveness of the component parts of each I-section in resisting the applied load.

KEY WORDS: bolts; efficiency; joints; rivets; steel; testing; trusses

(82)

Pauw, A., and Howard, L. L.
TENSION CONTROL FOR HIGH-STRENGTH STRUCTURAL BOLTS, Proceedings, AISC, April 1955, pp. 13-21.

Concepts of high-strength bolts are discussed. Proper design and assembly of joints make clamping force permanent, thus assuring that all loads will be transferred by frictional forces and that slip will be prevented. Correct pretensioning is essential. The results of tests of 1200 high-strength bolts tightened with a pneumatic impact wrench are given. Three variables were considered: wrench position, wrench type, and bolt size and length. Three methods of tension control of pneumatically-tightened bolts are discussed with respect to simplicity and economy. The first, checking selected bolts with a manual torque wrench, is inaccurate and uneconomical. The second, calibration of the impact wrench by adjusting air pressure for a specified torquing time, requires a special calibrating device and depends too much on wrench consistency. The third method, "turn of the nut", is under normal conditions a simple and effective means of tensioning bolts.

KEY WORDS: bolts; installing; pretensioning; testing

(83)

Ruble, E. J.
TURN-OF-THE-NUT METHOD, Proceedings, AISC, April 1955, pp. 21-26.

On-site installation of a few bolts with pneumatic impact wrenches or manual torque wrenches had proven impractical. The turn-of-the-nut method, used satisfactorily in the automotive industry, appeared to offer possibilities and an investigation of the method was initiated at AAR in 1954. Tests at the Association of American Railroads Research Center and at the University of Missouri led to the recommendation that one turn of the nut be accepted as a criterion of proper tension. The suggested procedure is as follows: (1) Draw the steel together using high-strength fitting-up bolts, (2) install the remaining bolts finger-tight and then give them one full turn, (3) give the fitting-up bolts an additional one-half turn.

KEY WORDS: bolts; installing; testing

(84)

Drew, F. P.
TIGHTENING HIGH STRENGTH BOLTS, Proceedings, ASCE, Vol. 81, Paper No. 786, August 1955.

A description of the several methods for tightening high-strength bolts is presented. The one-turn tightening method is dealt with in detail. Graphs showing the relationship between applied torque and nut turns, and between nut turns and impact wrench application time are included. The use of high-strength bolts in place of hot-driven rivets in erecting and maintaining steel bridges can save $440,000 a year for American railroads.

KEY WORDS: bolts; bolting

(85)

Pauw, A.
DISCUSSION OF ("TIGHTENING HIGH-STRENGTH BOLTS" by F. P. Drew), Proceedings, ASCE, Vol. 81, Paper No. 381, Nov. 1955.

Two questions are raised concerning the turn-of-nut procedure. (1) Can the adoption of the turn of the nut procedure under certain conditions lead to structural damage of the bolt, resulting in failure of the bolt or loss of clamping force? (2) If the concept of an "optimum target value" for the clamping force is abandoned, does the turn of the nut procedure necessarily provide the safest and simplest method for tension control? These questions are answered by studies at the University of Missouri. Bolt tensions achieved with pneumatic wrenches revealed that tensions equal to or greater than the minimum specified tensions are obtained with 0.6 to 0.9 revolutions of the nut for 7/8 in. bolts and 0.8 to 1.5 revolutions for 3/4 in. bolts. After the bolts were loosened, retightening requires about 1/4 of a revolution less than before to achieve specified tension. The turn of nut method appears to be adequate.

KEY WORDS: bolts; installing; prestressing

(86)

Mitchell, W. D., and Rosenthal, D.
INFLUENCE OF THE ELASTIC CONSTANTS ON THE PARTITION OF LOAD BETWEEN RIVETS, Proceedings of the Society for Experimental Stress Analysis, Vol. 7, No. 2, 1955, pp. 17-26.

The influence of fastener material on the distribution of load to individual fasteners is studied. "Joint modulus", property for the comparison of joints is introduced. It is defined as the movement of the outer plate with respect to the inner plates per unit load measured at the free outside end. It was found that to substantially improve the partition of load, the rivet material must be at least 10 times less rigid then the plate material. Also included is an electrical analog network for computation of the partition of load in the elastic range.

KEY WORDS: analyzing; distribution, load; rivets

(87)

AREA Committee on Iron and Steel Structures
USE OF HIGH STRENGTH STRUCTURAL BOLTS IN STEEL RAILWAY BRIDGES, Proceedings, AREA, Vol. 56, 1955, pp. 592-634.

Presented is the 3-part final report on Assignment 9 of the AREA committee on iron and steel structures. Part 1 presents details of an inspection in 1954 of experimental installations of high strength structural bolts in 15 railroad bridges to determine if bolts would stay tight in locations where rivets had loosened. Most of the bolts performed satisfactorily. Part 2 describes a method of tightening high-strength bolts in which bolt tension is correlated with turns of the nut from a "finger-tight" position. Drew (abstract no. 85) covers essentially the same material as Part 2. Part 3 presents the revised Specifications for Assembly of Structural Joints Using High Tensile Steel Bolts in Steel Railway Bridges.

KEY WORDS: bolts; bolting; specifications

(88)

Wyly, L. T., and Scott, M. B.
AN INVESTIGATION OF FATIGUE FAILURES IN STRUCTURAL MEMBERS OF ORE BRIDGES UNDER SERVICE LOADINGS, AREA Bulletin 524, 1955; (Also appeared in Proceedings, AREA, Vol. 57, 1956, pp. 175-298).

Data is presented on fatigue failures in ore bridges of the United States Steel Corporation. Significant factors in the failure in fatigue of the structural members are given, including riveted connection failure, fatigue cracks and strength of plates, state and gradient of stress, and others. A summary of laboratory tests on high-strength bolts shows that bolts can be substituted for hot-driven rivets.

KEY WORDS: bolts; bridge; fatigue; metalliferous material

(89)

Brady, W. G., and Drucker, D. C.
INVESTIGATION AND LIMIT ANALYSIS OF NET AREA IN TENSION, Transactions, ASCE, Vol. 120, 1955, pp. 1133-1164. (Appeared also as AN EXPERIMENTAL INVESTIGATION AND LIMIT ANALYSIS OF NET AREA IN TENSION, Proceedings, ASCE, Vol. 79, Separate No. 296, October 1953).

The results of an experimental investigation of the weakening effect of open holes in tension members and analysed according to the theory of plastic action. The technique is too complicated to be readily included in the already complicated elastic analysis of the gusset plate. Also presented is a list of references concerning the effect of holes, limit design, and safety factor as affected by holes.

KEY WORDS: gusset plate; holes; plasticity

(90)

Stewart, W. C.
HISTORY OF THE USE OF HIGH-STRENGTH BOLTS, Transactions, ASCE, Vol. 120, Paper No. 2778, 1955, pp. 1296-1298. (Appeared as THE WORK OF THE RESEARCH COUNCIL ON RIVETED AND BOLTED JOINTS, Proceedings, ASCE, Vol. 80, Separate No. 440, May 1954).

This paper was prepared as an introduction to a symposium on high-strength bolts in structural joints at the Centennial Convention of the ASCE at Chicago, Illinois, in 1952. The paper traces the history of the high-strength bolt and the organization of the Research Council on Riveted and Bolted Structural Joints. It also describes the origin and development of the first set of specifications prepared by the Council.

KEY WORDS: bolts; history; rivets

(91)

Munse, W. H., Wright, D. T., and Newmark, N. M.
LABORATORY TESTS OF BOLTED JOINTS, Transactions, ASCE, Vol. 120, Paper No. 2778, 1955, pp. 1299-1318. (Appeared as LABORATORY TESTS OF HIGH TENSILE BOLTED STRUCTURAL JOINTS, Proceedings, ASCE, Vol. 80, Separate No. 441, May 1954).

Results of static and fatigue tests conducted at the University of Illinois on structural joints using high tensile steel bolts are described. When the bolt tension exceeds 85% of elastic proof load, slip does not occur until plate stresses equal or slightly exceed normal working stresses. The type of joint-two-bolt or three-bolt lap joint or two-bolt butt joint-has little effect on the ultimate strength. The results indicate that the permissible shearing stress can be increased to 1.25 times the permissible tensile stress in order to obtain a balanced design. The high tensile bolts in the joint do not fail in fatigue. The fatigue strength of bolted joints is 25% greater than that of similar riveted joints. In short, high tensile bolted joints are generally superior to similar riveted joints in both static and fatigue loading.

KEY WORDS: bolts; fatigue; joints; rivets; slippage; tension

(92)

Francis, A. J.
DISCUSSION (ON "LABORATORY TESTS OF BOLTED JOINTS" by Munse, Wright, and Newmark), Transactions, ASCE, Vol. 120, 1955, pp. 1319-1320. (Also appeared in Proceedings, ASCE, Vol. 80, December 1954).

This is a discussion on the paper "Laboratory Tests of Bolted Joints" (Abstract No. 92). Mr. Francis notes that tests carried out for the Oakland Bay Bridge (California) have shown that the static strength of large joints failing in the rivets or bolts is less than the aggregate strength of the individual fasteners. Two factors - joint length and fasteners ductility have opposite effects on joint strength and therefore it is not clear whether rivets or bolts are more efficient. Mr. Francis also notes that the conclusion drawn by Mssrs. Munse, Wright, and Newmark about the ratio of bolt shearing stress to plate tensile stress does not appear justifiable. In a balanced design, this ratio would vary depending on the relative strengths of the bolt material and the plate material.

KEY WORDS: bolts; fastener; ratio, stress

(93)

Munse, W. H., Wright, D. T., and Newmark, N. M.
COMMENTS ON THE DISCUSSIONS (ON "LABORATORY TESTS OF BOLTED JOINTS"), Transactions, ASCE, Vol. 120, 1955, pp. 1320-1321. (Also appeared in Proceedings, ASCE, Vol. 81, April 1954).

The authors (Abstract No. 92) say that the A7 steel joint assembled with A325 bolts contained the same number of fasteners as the similar joints assembled with A141 steel rivets, and not fewer as Mr. Francis stated (see Abstract No. 93). Even in large long joints it has been found that a high-strength bolted joint is at least as strong as a similar riveted joint. The behavior of a bolted depends on the proportions of the connections and therefore on the shear tension ratio. Although only three riveted specimens were used for comparison of fatigue strengths, the results resembled those of many previous tests.

KEY WORDS: bolts; fatigue strength; joints; rivet

(94)

Baron, F., and Larson, E. W., Jr.
COMPARISON OF BOLTED AND RIVETED JOINTS, Transactions, ASCE, Vol. 120, Paper No. 2778, 1955, pp. 1322-1334. (Appeared as COMPARITIVE BEHAVIOR OF BOLTED AND RIVETED JOINTS, Proceedings, ASCE, Vol. 80, Sep. No. 470, August 1954. Also appeared as Research Report C109, Northwestern University, 1952).

The behaviors of bolted and riveted butt joints having a tension:shear:bearing ratio of about 1.00:0.75:1.50 and subjected to static and fatigue loads compared. The rivets were either hot or cold driven. The bolted joints were assembled with high-strength bolts. Several lengths of grip were considered for each type of fastener. Also considered were butt joints fastened with high-strength rivets and having a tension:shear:bearing ratio of 1.00:1.26:1.83. Seventy-four zero-to-tension and eighteen full reversal fatigue tests were conducted. Ten static tension tests were conducted to determine the relative behavior of joints. It was found that clamping force affects the fatigue strength of a joint and that fatigue strengths of bolted joints are greater than those of riveted joints. The plate efficiencies in both types of joints are the same irrespective of the kind of fastener and length of grip and are higher than 80%.

KEY WORDS: bolts; fatigue; force, clamping; joint; load, static; rivet

(95)

Hechtman, R. A., Young, D. R., Chin, A. G., and Savikko, E. R.
SLIP OF JOINTS UNDER STATIC LOADS, Transactions, ASCE, Vol. 120, Paper No. 2778, 1955, pp. 1335-1352. (Appeared first in Proceedings, ASCE, Vol. 80, Separate No. 484, August 1954. This report summarizes the material reported in Progress Reports 1, 2, and 3, ON SLIP OF STRUCTURAL STEEL DOUBLE LAP JOINTS ASSEMBLED WITH HIGH STRENGTH BOLTS TO RCRBSJ, University of Washington, January 1951, 1952, and 1953.

Slip in structural steel double-lap joints assembled with high-strength steel bolts and subjected to short-time static loading is analyzed. Altogether, 72 joints were tested; most were tested in tension, some in compression, and others in combined compression and torsion. Proper tightening of bolts prevented slip. Faying area, net cross-sectional area, thickness of lap plates, and number of rows of bolts in the joint are important factors affecting slip. Painted faying areas are not desirable for bolted joints. The joints were compared on the basis of shearing stress on bolts, coefficient of friction, slip, and stress on net cross-sectional area. The application of the Gullander method to the design of eccentrically loaded joints is found sound.

KEY WORDS: bolts; lap joint; load, static; slippage; tension

(96)

Carter, J. W., Lenzen, K. H., and Wyly, L. T.
FATIGUE IN RIVETED AND BOLTED SINGLE LAP JOINTS, Transactions, ASCE, Vol. 120, 1955, pp. 1353-1383. (Appeared first in Proceedings, Separate No. 469, ASCE, August 1954).

An explanation of, a working hypothesis for, and a remedy for fatigue failures in riveted and bolted single lap joints are presented. It is hypothesized that the index to the fatigue strength of a structural member is given by the magnitude of the tensile stress concentrations computed on an elastic basis and the total tensile strain concentrations to which the member is repeatedly subjected. The bearing of the rivets in the holes nearest the edge of the gussets at the failure section is the source of the high stress and strain concentrations which result in low hanger fatigue strength. A hypothesis is also given to explain the results of fatigue tests of double lap joints.

KEY WORDS: bolt; clamping; fatigue; force; lap joint; rivet; slippage

(97)

Higgins, T. R., Ruble, E. J.
STRUCTURAL USES OF HIGH STRENGTH BOLTS, Transactions, ASCE, Vol. 120, 1955, pp. 1389-1398. (Appeared first as STRUCTURAL APPLICATION OF HIGH STRENGTH BOLTS, Proceedings, ASCE, Separate No. 485, Vol. 80, September 1954.

Presented are examples of the use of high-strength bolts in building construction and a brief history of their use in structures. A description of various methods for controlling the torque exerted on the bolts by air impact wrenches is also included. Some of the work done by the Research Council is discussed along with the work which led to the present specifications. Possible future research and development of high-strength bolts are briefly discussed.

KEY WORDS: bolts; bolting; costs; structural engineering; utilization

(98)

Chesson, E., Jr., Petersen, K. S., Bell, W. G., and W. H. Munse
STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS, University of Illinois, Urbana, January 1956.

The progress of the test programs for the Research Council on Riveted and Bolted Structural Joints on Project I, II, III, IV, and VIII is reported (see Abstract 65). The scheduled and planned work of projects still in progress is also included. The Projects briefly discussed are: I-The Effect of Rivet Bearing on the Static and Fatigue Strength of the Plates of Riveted Joints, II-The Effect of Rivet Pattern on the Static Strength of Structural Joints, III-The Strength of Rivets in Shear and Combined Shear and Tension, IV-The Fatigue Strength of Bolted Structural Joints, and VIII-Fatigue Tests on Cumulative Damage in Structural Joints.

KEY WORDS: bolts; RCRBSJ; research; rivets; status reports

Popp, H. G., Hyler, W. S., and Grover, H. J.
THE EFFECT OF INTERFERENCE FIT ON THE FATIGUE BEHAVIOR OF MONOBLOCK SPECIMENS OF 7075-T ALCLAD SHEET, Battelle Memorial Institute, Columbus 1, Ohio, June 6, 1956.

The effect of interference on the fatigue behavior of monoblock specimens of 7075-T Alclad sheet is evaluated. The fatigue behavior of monoblock specimens can be improved with Huck-bolts assembled with interference fit. The improvement is greater for brazier-head Huck-bolts than for countersunk-head Huck-bolts. As the depth of the countersink was increased, the fatigue strength decreased.

KEY WORDS: bolt, huck; fatigue; fitting, interference; joint

(100)

Madison, R. B., and Vasarhelyi, D. D.
THE BEHAVIOR OF BOLTED JOINTS WITH MISALIGNED PUNCHED HOLES AND PAINTED FAYING SURFACES AT ROOM AND SUB-ZERO TEMPERATURE, Dept. of Civil Engineering, University of Washington, Sixth Progress Report, June 1956. (Summarized in EFFECTS OF FABRICATION TECHNIQUES, by D. D. Vasarhelyi, S. Y. Beano, R. B. Madison, Z. A. Lu, and U. C. Vasishth, Transactions, ASCE, Vol. 126, Part II, 1961, pp. 764-796.

The results of tests on 12 large bolted joints are presented. Two tension-shear ratios were investigated, 1.00:0.75 and 1:00:1.00. The tests were conducted to determine the effects of misaligned holes, punched holes, painted faying surfaces, and low temperatures on the behavior of structural steel double-lap joints assembled with high tensile steel bolts. The effect of misalignment of holes on efficiency and ultimate strength of joints was negligible. The ultimate strength, efficiency, elongation, and strain-energy absorption of joints with drilled holes were greater than those with punched holes. Red lead paint on the faying surfaces decreased the coefficient of friction by 2/3 at room temperature. At -25^{o}F the coefficient for unpainted mill scale and red lead painted faying surfaces was about the same. At -25^{o}F the ultimate strength and efficiency of the joints decreased 25% and the elongation and the strain energy absorbed decreased 80%.

KEY WORDS: bolts; hole; splitting; surface

(101)

Schijve, J.
THE FATIGUE STRENGTH OF RIVETED JOINTS AND LUGS, NACA TN 1395, Washington, August 1956.

The author examines the results of tests made by the National Luchtvaartlaboratorium in the Netherlands for the primary purpose of comparing several types of riveted joints and to study the effects of stress concentration factor, notch pattern, joint dimension, sheet thickness, dimpling mode, and other factors on the fatigue strength of lugs. In lugs in which the bolt is loaded in double shear, the theoretical stress concentration factor is approximately known, provided certain conditions are complied with. The most important of these is that the bolt is rigid enough so that bending can be discounted. The fit of the bolt itself has scarcely any effect on the stress concentration factor, provided the interference of the bolt is not too great. Recommendations for proportioning joints are made.

KEY WORDS: fatigue strength; lugs; rivet; stress concentration

(102)

Petersen, K. S., and Munse, W. H.
STATIC TENSION TESTS OF RIVETS AND HIGH STRENGTH BOLTS IN STRUCTURAL CONNECTIONS, Dept. of Civil Engineering, University of Illinois, SRS No. 124, November 1956.

The behavior of fasteners in a tension-type structural connection assembled with ASTM A325-53T high-strength bolts or A141 rivets is explained. The factors considered are the effect of the size and flexibility of the connected members and the effectiveness of the fasteners in members fabricated from wide-flange sections and assembled with more than two lines of fasteners. The tests show that four-fastener bolted specimens have efficiencies of 73.0 and 74.6% and similar riveted specimens have 101.1 and 77.1%. Eight-fastener specimens were only 49% efficient. The use of low prestress bolts of fully threaded bolts has little effect on the load-carrying capacity of the members. An increase in flange stiffness causes an increase in efficiency. The load carried by the riveted joints varied from 24% lower to 5% higher than that of similar bolted specimens.

KEY WORDS: bolts; fastener; rivet; tension

(103)

Jones, J.
BEARING-RATIO EFFECT ON STRENGTH OF RIVETED JOINTS, Transactions, ASCE, Paper No. 2949, Vol. 123, 1958, pp. 964-972. (Appeared as EFFECT OF BEARING RATIO ON STATIC STRENGTH OF RIVETED JOINTS, Journal of the Structural Division, ASCE, Paper No. 1108, Vol. 82, No. ST6, November 1956. Appeared also in Fasteners, Vol. 12, Nos. 2 and 3, Fall 1957.

The work of Project Committee No. 1 which included a review of prior work on the influence of bearing on static strength and an experimental program carried out in the structural laboratory of the University of Illinois between 1949 and 1951 is summarized. Seventeen static tests, eighteen tensile tests, six single shear tests, and eighteen compressive tests were included in this project. The experimental work and a review of the prior work led to the conclusion that the strength of joints loaded in tension does not decrease if the ratio of bearing pressure to the net tensile stress on the main material does not exceed 2.25. The strength of a joint loaded in compression or shear will also not decrease if the ratio of bearing pressure to shearing stress on the rivets does not exceed 3.00. Limits are recommended for the ratio of rivet shear to plate tension. There is no reason to differentiate between the allowable bearing pressure on a rivet stressed in single shear and that on a rivet stressed in double shear.

KEY WORDS: ratio, bearing; rivet; slippage; static test

(104)

Sanks, R. L.
TWO USEFUL GAGES MEASURE BOLT TENSION AND SLIP IN A JOINT, Civil Engineering, Vol. 26, No. 11, November 1956.

The details of the design and operation of load cells for the measurement of tension in high strength bolts and clip gages for the measurement of slip in joints are explained.

KEY WORDS: bolts; cell, load; joint; measuring instrument; slippage

(105)

Duffy, A. R.
STATIC MECHANICS OF A DOUBLE-STRAP BUTT JOINT CONNECTED WITH HIGH-STRENGTH BOLTS, M. S. Thesis, Purdue University, Lafayette, Indiana, 1956.

The behavior of a joint assembled with high-strength bolt is discussed in relation to the clamping force in the bolts, frictional resistance between plate surfaces, slip between adjacent plates, and load distribution throughout the joint. The test results show that slip is usually a local matter; that strain, clamping force, and slip are closely related; and that frictional resistance to slip is a non-uniform phenomenon.

KEY WORDS: bolts; force, clamping; joint; slippage

(106)

Munse, W. H.
RESEARCH ON BOLTED CONNECTIONS, Transactions, ASCE, Vol. 121, Paper No. 2839, 1956, pp. 1255-1266. (Appeared first as BOLTED CONNECTIONS RESEARCH, Proceedings, ASCE, Separate No. 650, March 1955. Distributed by Dept. of Civil Engineering, University of Illinois, as SRS No. 94, 1955).

The effects and advantages of high initial tension in high-strength bolts as determined in static and fatigue tests of bolts and bolted joints, and the general behavior of bolted joints subjected to static and repeated loads are presented in synoptic form. It is stated that the initial tension in the bolt must be as high as possible to maximize resistance to static and fatigue loadings.

KEY WORDS: bolts; structure; tension

(107)

Munse, W. H., and Cox, H. L.
THE STATIC STRENGTH OF RIVETS SUBJECTED TO COMBINED TENSION AND SHEAR, Bulletin, University of Illinois Engineering Experiment Station, Vol. 54, No. 437, No. 29, December 1956. (First distributed by Dept. of Civil Engineering, University of Illinois, as SRS No. 22, January 1952).

The strength and behavior of rivets subjected to various combinations of shear and tension are determined through results of 403 tests. The strength of rivets subjected to loads ranging from direct tension to direct shear is expressed as a non-dimensional elliptical interaction curve. The paper also shows the manner in which the yield strength, ultimate strength, and deformation of rivets are affected by such variables as rivet grip, rivet diameter, method of driving, and type of manufacture of rivets.

KEY WORDS: driving; ratio, shear-tension; rivets; soaking; strength, static; tensile strength

(108)

Krickenberger, C. F., Jr., Chesson, E., Jr., and Munse, W. H.
EVALUATION OF NUTS FOR USE WITH HIGH STRENGTH BOLTS, Dept. of Civil Engineering, University of Illinois, SRS No. 128, January 1957.

The results of tests of standard nuts and heavy nuts for A325 bolts are reported. The results show: (1) Regular series nuts are satisfactory for use with high strength bolts, particularly those nuts with medium carbon content or which have been cold worked or heat treated to increase their strength. Regular nuts of hardness less than 95 Rockwell B are unsatisfactory for 3/4 in. bolts. (2) Heavy series nuts of hardness less than 75 Rockwell B are unsatisfactory for 3/4 in. bolts. (3) All nuts give minimum specified bolt tension after one turn of the nut. (4) All nut and bolt assemblies retain tensions for a two day period. (5) Heavy series nuts require slightly longer impacting times for one turn and give slightly higher bolt tensions and smaller deformations than similar regular series nuts. (6) The average number of turns to failure is two for both regular and heavy series nuts.

KEY WORDS: bolts; nut; tension

(109)

Lu, Z. A., Vasishth, C., and Vasarhelyi, D. D.
TESTS OF LARGE BOLTED JOINTS TIGHTENED BY THE ONE-TURN-OF-THE-NUT METHOD, Dept. of Civil Engineering, University of Washington, Seattle, Seventh Progress Report to RCRBSJ, January 1957. (Summarized in EFFECTS OF FABRICATION TECHNIQUES, Transactions, ASCE, Vol. 126, Part II, 1961, pp. 764-796.

The bahvior of four large bolted joints tightened by the one-turn-of-the-nut method was investigated. The test joints were fabricated from two large joints which had been tested previously to determine their slip characteristics. The one-turn-of-the-nut method gave a lower coefficient of friction for the first major slip and a higher clamping force than the minimum-bolt-tension method. Calculated efficiencies agreed closely with experimental efficiencies.

KEY WORDS: bolts; fabrication; joints; tension

(110)

Godfrey, G. B.
POST-WAR DEVELOPMENTS IN GERMAN STEEL BRIDGES AND STRUCTURES, The Structural Engineer, Vol. XXXV, No. 2, London, February 1957.

Design developments in bridges and structures in post-war Germany are discussed. Included is a brief note on the use of high-strength bolts in bridges and structures and specifications for bolt holes, and recommendations for quality of bolts and nuts, tightening torque of nuts, and treatment of contact surfaces to provide frictional strength.

KEY WORDS: bolts; nuts; torque

(111)

Popp, H. G., Hyler, W. S., and Grover, H. J.
THE EFFECT OF INTERFERENCE FIT ON THE FATIGUE BEHAVIOR OF ALUMINUM-ALLOY JOINTS, Battelle Memorial Institute, Columbus 1, Ohio, April 19, 1957.

The effect of interference, clamping pressure, sheet material, sheet thickness-to-Huck-bolt-diameter ratio, surface lubricants, and adhesives on the fatigue performance of joints assembled with Huck-bolt pins is investigated. The experimental fatigue data for joints assembled with interference of 0.000 and 0.007 in. between hole and Huck-bolt pin was obtained at three nominal values of clamping force: 0, 1300, and 2500 lbs. Fatigue behavior of single-shear and double-shear lap joints assembled with or without moderate values of preload can be improved by assembling the Huck-bolt pins in interference as well as by high clamping forces. Fretting corrosion between the faying sheets is the most important factor governing the fatigue behavior of the joint. However, fretting failures can be relieved with pliable adhesives.

KEY WORDS: aluminum alloy; bolt, huck; butt joint; fatigue; fitting, interference; force, clamping; lap joint

(112)

Wyly, T., Treanor, H. E., and LaRoy, H. E.
DEMONSTRATION TEST OF AN A242 HIGH-STRENGTH STEEL SPECIMEN CONNECTED BY A325 AND BY A354 BOLTS, Proceedings, AISC, National Engineering Conference, Northwestern University, Evanston, Illinois, May 28, 1957.

The behavior of high-strength steel joints assembled with high-strength bolts and subjected to tension is discussed. The reserve capacity for load at the first major slip is substantial. Increase in clamping force increases the friction force and the carrying capacity for A242 steel without slip increases with the increase in clamping force. The A325 bolted connection developed the full tensile strength of the main plate material at the net section.

KEY WORDS: bolts; friction; joint; slippage; tension; torque

(113)

White, M. W., and Thurlimann, B.
STUDY OF COLUMNS WITH PERFORATED COVER PLATES, Proceedings, AREA, Vol. 58, 1957, pp. 173-292.

This report presents a complete analytical and laboratory study of the strength of columns showing perforated cover plates in place of the lacing system or batten plates. Previous studies are reviewed and an analytical study of eccentrically and concentrically loaded columns, taking into account axial rigidity, bending stiffness, transverse shear, local buckling and stress concentration due to the perforation in presented. Two full size riveted columns were tested to failure. The columns were designed to existing specifications and the cross-section dimensions and perforation spacing was similar to the diagonal members used in the bridge over the Mississippi River at New Orleans, La. One column was fabricated from A7 steel and the other from a new high-strength steel. The tests were conducted to determine and compare their ultimate strengths, to check current design prodedure and to check the analysis. The results indicate that the ultimate capacity was closely predicted using the tangent modulus. Also, the beginning of local buckling was not catastrophic. Design recommendations based on the analytical studies are given.

KEY WORDS: analyzing; columns; plates, cover; rivet; steel; testing

(114)

Easton, F. M., Lewis, E. M., and Wright, D. T.
SOME NOTES ON THE USE OF HIGH PRELOAD BOLTS IN THE UNITED KINGDOM, The Structural Engineer, Vol. XXXV, No. 5, London, May 1957, pp. 167-175.

The theory of friction grip joints, the theory of tightening high preload bolted connections, the half-torque-half-turn technique, the Western Region code of practice of British Railways, and laboratory tests are discussed in synoptic form. The authors conclude that bolts to British Standard Specifications could be used either with the torque coefficient or the turn-limiting technique to produce satisfactory joints. Power tools might replace manual wrenches with large bolts in the torque coefficient technique. Because of the advantages of strain limiting technique, the "half-torque-half-turn" could be adopted widely in conjunction with power tightening supplemented by manual methods.

KEY WORDS: bolts; friction; pretensioning; utilizations

(115)

Institution of Structural Engineers
DISCUSSION (OF "SOME NOTES ON THE USE OF HIGH PRELOAD BOLTS IN THE UNITED KINGDOM", by Easton, Lewis, and Wright), The Structural Engineer, Vol. XXXV, No. 5, London, May 1957, pp. 228-242.

After discussion it is concluded that a single tool could be used to apply the half-torque-half-turn technique. An impact wrench capable of applying the final part-turn could easily be modified to indicate the part-torque. Preload induced in service by the applied torque was higher than expected and resulted in thread stripping. Decrease of preload is discussed, and it is concluded that even if the stress in a bolt were not allowed to exceed the limit of proportionality there might still be some loss of preload in cyclic load application.

KEY WORDS: bolts; pretensioning; torque

(116)

Bell, M. H.
HIGH-STRENGTH STEEL BOLTS IN STRUCTURAL PRACTICE, Transactions, ASCE, Vol. 122, Paper No. 2845, 1957, pp. 1-21. (Appeared in Proceedings, ASCE, Separate No. 651, March 1955).

A brief history of the development of the high-strength bolt is presented together with a resume of the development of specifications for field assembly using these bolts. The use of the pneumatic wrench procedures for determining bolt tension are described. Many examples of the use of high-strength bolts are cited and illustrated.

KEY WORDS: bolts; specifications; utilizations

(117)

Thrasher, J. Q.
"SILENCE, IT'S GOLDEN!" Steelways, June 1957, pp. 22-23.

Presented is a brief history of the tendency to change from rivets to high-strength bolts for use as structural fasteners. The organization and development of the Research Council, its sponsors, and the work done by the engineering schools of five universities - Northwestern, Purdue, Illinois, Washington (at Seattle), and Lehigh - are discussed. The advantages of bolts over rivets, including lower noise, lower cost, and easier and faster installation and replacement, are noted.

KEY WORDS: bolts; economic factors; RCRBSJ; rivets

(118)

Douty, R. T.
CHARACTERISTICS OF FLEXIBLE FLANGE CONNECTIONS AND FASTENERS, M. S. Thesis, Georgia Institute of Technology, June 1957.

Presented is an investigation of the characteristics of a connection employing a flexible flange and a study of the additional load placed on the fasteners as a result of prying action of the flange. Test specimens consisted of six tee sections connected with A325 bolts and eight brackets fabricated of plates welded together. Equations are developed for computation of the effect of strain hardening of the flange on fastener tension. Initial pretension of fasteners has no effect on the ultimate load of high-tensile-strength bolted-flange-type connections. Also included are recommendations for design which incorporate the results of the investigation.

KEY WORDS: brackets; fasteners; flange; plastic analysis; tension

(119)

Vasishth, U. C., Lu, Z. A., and Vasarhelyi, D. D.
A STUDY OF THE NOMINAL COEFFICIENT OF FRICTION IN STRUCTURAL STEEL JOINTS FASTENED BY HIGH TENSILE BOLTS, Dept. of Civil Engineering, University of Washington, Eighth Progress Report to RCRBSJ, June 1957. (Summarized in EFFECTS OF FABRICATION TECHNIQUES, Transactions, ASCE, Vol. 126, Paper No. 1973, 1961, pp. 764-796).

The report analyses the slip characteristics of various joints fastened with high-strength bolts and subjected to static loading. It includes information on the effects of the one-turn-of-the-nut method on 4-bolt joints. The condition of the faying surfaces determines the value of the coefficient of friction. The factors that reduce the coefficient of friction are: (1) increasing bolt tension, (2) decreasing tension-shear ratio, (3) increasing size of joint, (4) increasing number of bolts, and (5) sustained loading.

KEY WORDS: bolts; friction; slippage; surface, faying; tension

(120)

Munse, W. H.
AN EVALUATION OF THE BEHAVIOR OF STRUCTURAL CONNECTIONS ASSEMBLED WITH HOOK-KNURL BOLTS, University of Illinois, September 1957.

Five double-lap splices assembled with high-strength bolts and 9 similar joints assembled with Hook-Knurl bolts behaved similarly under static and fatigue loading. However, joints with Hook-Knurl bolts were superior to those with high-strength bolts under slip-producing conditions, while the joints with high-strength bolts were slightly superior under fatigue loading.

KEY WORDS: bolts; butt joints; fatigue; static test; testing

(121)

Chauner, R. W., and Vasarhelyi, D. D.
DOES VIBRATION AFFECT FRICTION IN A BOLTED JOINT, The Trend in Engineering, University of Washington, Seattle, Vol. 9, No. 4, October 1957, pp. 23-29.

Sixty-five tests were run on one bolted double-lap joint. The faying surfaces were belt-sanded to remove all mill scale. In most cases, load was applied until noticeable slip was reached. After slip the specimen was dismounted and new fasteners were installed. Three different levels of clamping force were investigated. For each range of clamping force, the joint was subjected to static tension loading with and without vibration. There is a 6 to 8% decrease in the load required to cause slip of a bolted steel joint if vibrations on the order of 1800 cps are present. There is a decrease in the coefficient of friction under vibrational loading.

KEY WORDS: bolts; friction; joint; steel; vibration

(122)

Feeser, L. J.
BOLT SHEAR TESTS, Final Report for C. E. 103, Lehigh University, Bethlehem, Pa., 1957.

Tests were performed at Lehigh University, Bethlehem, Pennsylvania, on 7/8 in. and 1 in. tensioned high-strength bolts to find the shearing strength. Tension load applied by tightening the nut was measured on the dial of a 300k testing machine. Shearing load was applied by the 300k testing machine. The results are analyzed by the use of Distortion Energy theory. The calculated ultimate shearing stress is higher than that given for A325 bolts from data in which bending and frictional shear are not included, and the yield stress is about 40 ksi, which is approximately 2.65 times the AISC allowable 15 ksi.

KEY WORDS: bolt; shear strength; tension; yield point

(123)

Wyly, L. T.
FATIGUE STUDIES ON STRUCTURAL JOINTS OF ASTM A-7 AND A-242 HIGH STRENGTH STEEL, Proceedings, AISC National Engineering Conference, New York, 1957, pp. 56-65.

Data on the fatigue properties of structural joints is presented from field and laboratory investigations. The clamping force in structural joints is highly critical in fatigue applications. In general, bolted joints show better fatigue resistance because they are free from the local stress and strain concentrations and the varying clamping forces which characterize riveted joints. Fatigue failure in riveted joints may be prevented by replacing the rivets with high-strength bolts prevented from bearing on the plates by ample hole clearance and tightened sufficiently to produce enough clamping force to prevent slip and to provide an initial compression stress and strain at the sides of the holes.

KEY WORDS: bolts; design; fatigue; joints; rivets

(124)

Holt, J. A.
300,000 HIGH STRENGTH BOLTS-WORLD'S RECORD IN BRIDGE CONSTRUCTION, Fasteners, Vol. 12, Nos. 2 and 3, Fall 1957, pp. 2-3.

The use of 300,000 high-strength bolts, a record number for one project, is discussed. These 3/4 in. and 7/8 in. bolts (some of the 7/8 in. size with countersunk heads) were manufactured to specifications and installed with pneumatic wrenches. Torque was controlled by running the wrench to "stall" on a predetermined air pressure. The "full-turn-of-the-nut" procedure (AREA Bulletin 520) was tried, but it took longer than the "stall" method because initial hand tightening of the nut was required. A No. 325 Warren and Brown Manual torque wrench was used to test installed fasteners. The average total cost per fastener in place, including wrench maintainance was about $0.50.

KEY WORDS: bolts; bridge construction; fabrication; installing

(125)

Beano, S. Y., and Vasarhelyi, D. D.
THE EFFECT OF VARIOUS TREATMENTS OF THE FAYING SURFACES ON THE COEFFICIENT OF FRICTION IN BOLTED JOINTS, Dept. of Civil Engineering, University of Washington, Ninth Progress Report to RCRBSJ, January 1958. (Summarized in EFFECTS OF FABRICATION TECHNIQUES, Transactions, ASCE, Vol. 126, Paper No. 1973, 1961, pp. 764-796).

Tests were made at the University of Washington to supplement previous tests (see Abstract 120) and to determine the effect of faying surface treatment on the coefficient of friction in bolted joints using high-strength bolts. The faying surfaces were thoroughly cleaned either by fire or sand blast and then in some cases treated with either red lead paint or profilm plastic of different grades. The results suggest that profilm develops friction greater than red lead and that a metallic bond contributes to friction. The slip test employed herein for determining the nominal coefficient of friction can be standardized as a test for comparison of frictional behavior of faying surfaces in structural joints.

KEY WORDS: bolt; friction; joint; slippage; surface, faying

(126)

Frincke, M. H.
TURN-OF-NUT METHOD FOR TENSIONING BOLTS, Civil Engineering, Vol. 28, No. 1, January 1958.

The development of a modified turn-of-nut method adopted by The Bethlehem Pacific Coast Corporation is outlined. The method is described. The nut is run up to a snug position with an impact wrench and is then given an additional 1/2 or 3/4 turn, depending on bolt length. A table listing compressor capacities for impact wrenches is given. Bolts assembled with this procedure will have no less than the minimum specified tension.

KEY WORDS: bolts; installing; prestressing

(127)

McDonald, D., Ang, A., and Massard, J. M.
AN INVESTIGATION OF RIVETED AND BOLTED COLUMN-BASE AND BEAM-TO-COLUMN CONNECTIONS UNDER SLOW AND RAPID LOADING, Dept. of Civil Engineering, University of Illinois, February 1958.

Presented are a description of and results from slow and rapid load tests to determine the resistance characteristics of riveted and bolted column-base and beam-to-column connections. The investigation was limited by the small number of specimens and the lack of variety of connections. The tests clearly indicate that the rate of deformation had a greater resistance of the connection: rapidly deformed specimens had a greater resistance at a given deflection than those deformed slowly. The type of fastener had little effect on the moment-rotation characteristics of the connections studied. Also presented is a procedure which accounts for strain hardening in the evaluation of resistance of a frame with semi-rigid connections as it is loaded into the inelastic range.

KEY WORDS: column; fastener; joint, beam-to-column; resistance

(128)

Stetina, H. J.
CHOOSING THE RIGHT FASTENER, Proceedings, AISC National Engineering Conference, April 1958, pp. 49-55.

Economical and practical design considerations in the selection of a fastener are presented in synoptic form. They are: shear, bearing, tension, efficiency of the joint , fatigue, joint slippage , vibration, appearance , maintenance, installation clearance portability and noise abatement. A table is presented which shows material and direct labor costs for installing these field fasteners: rivets, ribbed bolts, high-strength bolts , unfinished bolts , and 5/16 in. fillet welds. Method of erection is a practical consideration in fastener choice.

KEY WORDS: bolts; design; joints; rivets; welded joints

(129)

Munse, W. H. Fuller J. R., and Petersen K. S.
CUMULATIVE DAMAGE IN STRUCTURAL JOINTS, Bulletin, AREA, No. 544, June-July 1958 p. 67. (First Distributed by Dept. of Civil Engineering, University of Illinois, as ARS No. 127, January 1957; Also appeared in Proceedings, AREA, Vol. 60, 1959, pp. 67-128).

Explained is the need for a 50,000 lb. variable-cycle fatigue testing machine to help investigate cumulative fatigue damage to and determine the fatigue lives of double strap butt joints and plain plate specimens. It also deals at length with the cumulative damage in fatigue, spectrum-type fatigue tests, the statistical nature of fatigue test results, variable-cycle fatigue machines, and static tests. Extensive use is made of data from rotating beam tests and from previous fatigue damage studies. An empirical method is proposed estimating fatigue lives of structural joints tested under a spectrum-type loading pattern.

KEY WORDS: fatigue; joints; stresses

(130)

Engineering News-Record
STEEL FASTENER COSTS COMPARED, Engineering News-Record, September 18, 1958. (Discussed in COST OF FIELD FASTENERS, a letter to the editor, by A. J. Julicher, Engineering News-Record, December 18, 1958).

This is an analysis of how high-strength bolt, rivet, and welding costs vary with production rates. Welding has low labor and material costs and high equipment cost, bolts have low labor and equipment costs but high material cost, and rivets have low material and equipment costs and high labor cost. Bolting saves time and reduces overhead. On the whole, the study favors high-strength bolts over rivets and welds.

KEY WORDS: bolts; costs; fastener; rivet

(131)

Chesson, E., Jr., and Munse, W. H.
BEHAVIOR OF RIVETED TRUSS-TYPE CONNECTIONS, Transactions, ASCE, Vol. 123, 1958, pp. 1087-1128. (Appeared as A STUDY OF THE BEHAVIOR OF RIVETED CONNECTIONS IN TRUSS-TYPE MEMBERS, Journal of the Structural Division, ASCE, Vol 83, No. ST1, Proc. Paper No. 1150, January 1957. Distributed by University of Illinois first as SRS No. 132, 1957. Greater detail is given in BRS No. 115, January 1956.

Specimen configuration, method of hole preparation, and rivet size were the main variables considered in 16 tests of 5 types of truss-type riveted structural connections. Shear failures may be expected in long truss-type joints of "balanced design". The distribution of rivets in a joint should be similar to the distribution of areas connected to those rivets. Members with drilled holes were more susceptible to shear failures than were similar punched specimens. Larger rivet diameters and the resulting smaller number of holes may improve shear strength of large connections. To avoid gusset failure, narrower and stiffer gussets are preferred over thinner gussets having the same net area. To avoid tensile failures at lacing rivets, the edge distances should be made as large as possible. The efficiency of punched specimens and drilled specimens varies only slightly. The AREA net section rule can be used as a basis for efficiency specifications.

KEY WORDS: efficiency; gusset plates; joint; rivets; trusses

(132)

Foreman, R. T., and Rumpf, J. L.
STATIC TENSION TESTS OF BOLTED JOINTS, Fritz Engineering Laboratory Report No. 271.1, Lehigh University, Bethlehem, Pa., December 1958. (Summarized in STATIC TENSION TESTS OF COMPACT BOLTED JOINTS, Transactions, ASCE, Vol. 126, Paper No. 3125, 1961, pp. 228-254).

Six large butt joints of A7 steel connected with 7/8 in. A325 bolts were tested to failure under static loading. The fasteners were usually arranged in compact patterns with three to six fasteners in a line. Five joints had five lines of bolts and one had six lines. All bolts were installed by the turn-of-nut procedure. The specimens were designed with various tension-shear ratios (the ratio of the tensile stress on the net section of the plate to the shear stress on the fasteners). One riveted joint containing 25-7/8 in. A141 steel rivets was tested to provide comparative data. Results indicated that simultaneous failure in the A325 bolts and A7 steel plate would occur when the net plate area was approximately 110% of the bolt shear area. Major slip occurred at nominal bolt shear stresses which were 75% to 125% in excess of normal working stresses. The average slip coefficient was approximately 0.4.

KEY WORDS: bolts; joints; slippage; steel; strength; structural engineering; testing

(133)

Ruble, E. J.
BEHIND THE SCENES IN THE DEVELOPMENT OF THE ASTM HIGH-STRENGTH BOLT SPECIFICATIONS, Fasteners, Vol. 13, No. 3, 1958, pp. 3-5.

A review of the principal changes in bolts along with an outline of the specifications for high-strength bolts and heavy nuts are presented. The ASTM A325 specification requires that the bolt dimensions conform with ASA Specifications B-18.2 for regular semi-finished hexagon bolts. The heavy hexagon nuts should conform to the ASA Specification B-27.2, having their proof load based on a unit stress of 144,000 psi for sizes up to 1-1/2 in. This is an increase in proof load of over 25 percent for the 7/8 in. and 1 in. bolts.

KEY WORDS: bolts; nuts; specification; washers

(134)

Waltermine, W. G.
NEW HIGH TENSILE BEARING BOLT, Proceedings, AISC National Engineering Conference, 1958.

Characteristics, test results, and service findings of high-strength bearing bolts are presented. The performance of these bolts in joints is compared with that of rivets and ordinary high-strength bolts with respect to static strength, fatigue strength, slippage, and shock capacity. High-strength bearing bolts have advantages over ordinary high-strength bolts.

KEY WORDS: bolts; joints; steel; structural engineering; testing

(135)

Foreman, R. T., and Rumpf, J. L.
FURTHER STATIC TENSION TESTS OF BOLTED JOINTS, Fritz Engineering Laboratory Report No. 271.2, Lehigh University, Bethlehem, Pa., December 1958. (Summarized in STATIC TENSION TESTS OF COMPACT BOLTED JOINTS, Transactions, ASCE, Vol. 126, Paper No. 3125, 1961, pp. 228-254).

Two test specimens, double-lap tension splices, one assembled with 1 in. A325 bolts and the other with 1-1/8 in. A325 bolts were proportioned with the net plate area equal to 110% of the bolt shear area. The joint with 1 in. bolts had 4 longitudinal lines and 4 transverse lines of bolts, while the one with 1-1/8 in. bolts had 4 lines and 3 rows. Bolt failures occurred when the tensile stresses on the net section were well above the average coupon strength. Major slip occurred at nominal bolt shear stresses which were 120 to 140% in excess of normal working stresses for friction-type joints.

KEY WORDS: bolts; joints; slippage; steel; strength; structural engineering; testing

(136)

Rumpf, J. L.
SHEAR RESISTANCE OF HIGH STRENGTH BOLTS, Fritz Engineering Laboratory Report No. 271.3, Lehigh University, Bethlehem, Pa., 1958. (Summarized in STATIC TENSION TESTS OF COMPACT BOLTED JOINTS, Transactions, ASCE, Vol. 126, Paper No. 3125, 1961, pp. 228-254).

This report is a summary of an investigation to determine the shear strength of a single A325 bolt subjected to double shear. Single bolts were subjected to double shear by applying a compressive load to the plates of the shear jig. The initial internal bolt tension was varied from zero to a maximum which corresponded to the internal tension induced by 1/2, or 1, or 1-1/2 turns-of-the-nut. The faying surfaces were either clean mill scale or mill scale lubricated with Molycote. The ultimate double shear strength of the bolt was unaffected by the amount of initial bolt tension. Bolts joining plates with clean mill scale surfaces showed a slight increase in shear strength over bolts connecting lubricated plates.

KEY WORDS: bolts; joint; steel; structural engineering; testing

(137)

Lewitt, C. W., Chesson, E., Jr., and Munse, W. H.
THE EFFECT OF RIVET BEARING ON THE FATIGUE STRENGTH OF RIVETED JOINTS, University of Illinois, SRS No. 170, January 1959.

The effect is reported of bearing pressure on the fatigue strength of A7 steel joints fastened with two rows of hot-formed, hot-driven A141 steel rivets. Twenty-six zero-to-tension tests and eight full-reversal tests were made. The bearing to tension ratios studied were 1.37, 1.84, 2.36, and 2.74. The zero-to-tension tests show that an increase in fatigue life is accompanied by a decrease in bearing pressure. The number of full reversal tests was insufficient to isolate the relationship of fatigue strength to bearing ratio. Also, the average clamping force of rivets increased with an increase in grip and increased clamping force was accompanied by, and probably caused, an increase in fatigue life.

KEY WORDS: bearing; fatigue strength; joints; rivet

(138)

Chesson, E., Jr., Lewitt, C. W., Dineen, R. L., and Munse, W. H.
STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS, University of Illinois, Urbana, January 1959.

Projects I - Effect of Rivet Bearing on the Static and Fatigue Strength of Riveted Joints, II - Effect of Rivet Pattern on the Static and Fatigue Strength of Bolted Structural Joints, and VIII - Fatigue Tests on Cumulative Damage in Structural Joints are briefly discussed to indicate which parts of the program had been completed or were in progress. Summaries of the results of those portions of the completed programs are presented.

KEY WORDS: RCRBSJ; status report

(139)

Munse, W. H.
STUDY OF THE EFFECT OF FLANGED NUTS ON THE FATIGUE BEHAVIOR OF FLAT PLATES, University of Illinois, Urbana, January 1959.

The effects of flanged nuts on the fatigue behavior of structural steel are presented. The tests show that the fatigue strength of a plate with an open hole does not decrease as a result of turning a flanged nut on the surface of the plate. Gripping or keying action of the flanged nut coupled with the high clamping force of the bolt provides an increase in the fatigue strength of the plate. In general, the strength of members in joints assembled with flanged nuts is equal to or greater than that of members in joints assembled with ordinary nuts for A325 bolts.

KEY WORDS: bolt; fatigue strength; nuts; plates, flat; washers

(140)

Stafford, R. W., Lewitt, C. W., and Chesson, E., Jr.
PRELIMINARY TESTS OF HIGH STRENGTH BOLTS UNDER COMBINED SHEAR AND TENSION, University of Illinois, Urbana, February 1959.

Sixteen tests were made on 3/4 in. high-strength bolts of both 2.75 and 4.00 in. in length. The bolts were loaded in tension-shear ratios of from 1.0:0 to 1.0:0.67. The 4 in. bolts failed through the threads at T:S = 1.0:0, 1.0:0.20, and 1.0:0.42. The 2.75 in. bolts failed in the shanks at angles of fracture from approximately 90° to 45° with the bolt axes. The ratio of tensile strength to shear strength was 1.26. Also presented is a proposal for a future testing program including further investigation of the grip, thread length, T:S ratio, bolt strength, bolt diameter, deformation measurements, and material in shear blocks. A proposal for a second series of tests concerning impact loadings and fatigue loadings is briefly discussed.

KEY WORDS: bolt; tension; ratio, shear

(141)

Kaplan, S.
DOUBLE SHEAR TESTS OF HIGH STRENGTH BOLTS, Fritz Engineering Laboratory Report No. 271. 4, Lehigh University, Bethlehem, Pennsylvania, April 1959.

A series of tests under compressive loading was conducted on 60 single-bolt, double-shear test jigs to determine the double-shear strength of an A325 high-strength bolt. Both 7/8 in. and 1 in. bolts were tested. The bolts were tightened to various degrees of initial tension which varied from zero to a maximum equal to the internal tension induced by 1/2, 1, or 1-1/2 turns of the nut. The faying surfaces were either clean mill scale or mill scale lubricated with Molycote. The ultimate double shear strength of the bolt was unaffected by the amount of initial bolt tension. Bolts joining plates with clean mill scale surfaces had higher shear strengths than bolts connecting lubricated plates. The shear strength of a single bolt was approximately 70% of the tensile strength as determined by a static tension test.

KEY WORDS: bolts; joints; steel; structural engineering; testing

(142)

Schutz, F. W., Jr.
STRENGTH OF MOMENT CONNECTIONS USING HIGH TENSILE STRENGTH BOLTS, Proceedings, AISC, 1959, pp. 98-110.

Recent research is used to support a proposal for the development of an improved analysis and design procedure for moment connections using high-strength bolts. Typical test results are given for tee section moment connections, butt type moment connections, and conventional beam splices. The new design method can be based logically on some of the fundamentals of plastic analysis and design of rigid steel frames. Plastic design of bolted connections can reduce the number of bolts required and the amount of steel in connection parts, and increase usable space above and below beam ends. Several connections designed with the proposed criteria are compared with typical riveted and bolted connections.

KEY WORDS: analyzing; bolts; joints; steel; structural engineering

(143)

Munse, W. H.
THE EFFECT OF BEARING PRESSURE ON THE STATIC STRENGTH OF RIVETED CONNECTIONS, Bulletin, No. 454, University of Illinois Engineering Experiment Station, July 1959.

The effect of bearing pressure on the static strength and behavior of riveted connections is determined from tensile and compression tests of 131 riveted joints. In the tensile tests the bearing ratio-the ratio of bearing stress to tensile stress-varied from 1.28 to 3.05, while in the compression tests the ratio varied from 1.78 to 4.21. Under static tensile loading, the strength or efficiency of the riveted joint is not reduced as a result of increasing the bearing stress to a value of 2.25 times the tensile stress in the connections. The increase in efficiency normally expected from the wide gage distances necessary for high bearing stress may not be fully realized.

KEY WORDS: bearing; joint; rivet; strength, static

(144)

Societe de la Tour Eiffel
THE EIFFEL TOWER AFTER 70 YEARS, Fasteners, Vol. 14, No. 1, Spring 1959, pp. 7-8.

This article describes briefly the history of the Eiffel Tower, which was 70 years old in 1959. The tower is composed of 15,000 steel members connected by 2,500,000 rivets. It is 1025 ft. above ground and is supported by four legs which join at the second story, 380 ft. above the ground. The tower can resist an 82 lb. per sq. ft. wind load, and the top may move in a 7 in. circle due to member elongations on a sunny day. Rivet maintenance on the tower has been negligible, but it has to be painted every seven years.

KEY WORDS: loads, wind; maintenance; publicity; riveted joints

(145)

Young, W. C.
RESULTS OF TESTS OF STRUCTURAL CONNECTIONS ASSEMBLED WITH HIGH TENSILE STRUCTURAL RIB BOLTS-INTERUPTED RIBS, University of Wisconsin, May 1959.

The properties of structural steel lap and butt joints jointed with American Standard High-Strength Hexagon Head Bolts, ASTM A325 are compared to the properties of similar joined with high-strength structural rib bolts, ASTM A325. Up to a certain point the characteristics of these joints are identical. Beyond this point, the interference fit of the rib bolts prevents slip. For loads up to 40,000 lb. for the lap joints and 71,000 lb. for butt joints, the deformation of the joints using rib bolts are the same regardless of the type of nut and washer used. In addition, rib bolts carry greater shearing load at failure than ordinary A325 bolts.

KEY WORDS: bolt; deformation; structure; tension

(146)

Steinhardt, O.
THE GERMAN CONTRIBUTION TO RESEARCH, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 2-9.

This paper reports the German contribution to research concerning such aspects of strength bolts as bolt stresses, slip resistance, behavior under static and dynamic loading, bolt tension, extension of joints with increasing loads, types of construction with high strength bolts, and practical application. However, the paper is mainly concerned with slip resistance. The results of tests to determine the coefficient of friction are summarized. Treatment of the contact surfaces was shown to increase frictional resistance. A marked increase was noted for double or oblique flame-cleaned ST52 high-tensile steel. The coefficient of friction if for mild steel ranged from 0.181 to 0.593 for surface brushed and cleaned from 0.430 to 0.767 for surfaces sandblasted, and from 0.335 to 0.751 for surface flame cleaned. For high tensile steel the coefficient were 0.382 to 0.466 for surface brushed and from 0.574 to 0.805 for simple flame cleaning. A few tests of joints fastened with both high strength bolts and welds showed good interaction up to the limits of friction.

KEY WORDS: bolts; fatigue; friction; joint; load; research; slippage; static test

(147)

Godfrey, G. B.
SPECIFICATIONS FOR HIGH STRENGTH BOLTS, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 10-13.

This paper contains a brief history of high-strength bolts in various countries, American Specifications for assembly of structural joints using high strength bolts, and a comparison of American specifications with those of other countries. An explanation and analysis of British design of high-strength bolted joints is presented.

KEY WORDS: bolts; joint; specifications

(148)

German Committee for Structural Steelwork
APPENDIX-A TRANSLATION OF THE PRELIMINARY DIRECTIVES FOR THE CALCULATION, DESIGN AND ASSEMBLY OF NON-SLIP, BOLTED CONNECTIONS (H. S. CONNECTIONS) FOR STEEL STRUCTURES, BRIDGES AND CRANES, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 14-19.

Directives for the calculation, design, and assembly of non-slip high-strength bolted connections issued by the German Committee for Structural Steelwork are explained in this appendix. The principles for calculation of permissible loads, stresses, and bearing pressures are given in condensed form. The design considerations include the choice of the material and dimensions of bolts, nuts, and washers, and the treatment of the contact surfaces. A brief procedure for assembly and tensioning of bolts is prescribed.

KEY WORDS: bolts; computation; design; instructions; joints; structural engineering

(149)

Alder, J. F.
EXPLORATORY TESTS ON FRICTION GRIP BOLTED JOINTS, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 19-27.

Investigated are the contact surface conditions and the bolt tightening torques required to transmit a working load of 5 tons per bolt per contact surface with a safety factor of 1.5 in a structural joint assembled with mild steel plates and 1 in. diameter UNF high-tensile steel bolts. The test specimens were double lap joints containing 1, 4, or 6 bolts. The slips were measured under static and dynamic loads. It was found that untreated rusty surfaces require a torque of at least 600 pounds-feet for static loading and 700 pounds-feet for dynamic loading.

KEY WORDS: bolt; friction; joint; torque

(150)

Ranger, B. E. S.
DEVELOPMENT OF A MOMENT CONNECTION FOR RIGID FRAMES, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 28-36.

The behavior and design of a rigid beam-to-column connection assembled with special grade high-strength steel bolts and intended to transmit "fixed-end" moments and wind moments were fully examined. The behavior of the beam connection under load was studied by subjecting a full-size moment connection simultaneously to moment and shear. Graphs of deflection and separation of the end plate from the column were plotted as functions of load. Because the separation curves were observed by local deformation, it is difficult to predict the load at which separation occurs. Slip was not observed even at maximum load.

KEY WORDS: bolt; joint, rigid frame; moment; shear

(151)

Lancaster, N.
THE USE OF HIGH STRENGTH FRICTION GRIP BOLTS IN STRUCTURES, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 36-43.

A brief history of the use of high-strength friction-grip bolts is presented along with a discussion of their advantages as an alternative to rivets or fitted bolts in site connections. The results of 108 tests to determine the torque-tension relationship for 3/4 in. bolts are presented graphically.

KEY WORDS: bolt; structure; utilization

(152)

Hojarczyk, S., Kasinski, J., and Nawrat, T.
LOAD-SLIP CHARACTERISTICS OF HIGH STRENGTH BOLTED STRUCTURAL JOINTS PROTECTED FROM CORROSION BY VARIOUS SPRAYED COATINGS, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 43-48.

Investigated was the effect of sprayed metal coatings of faying surfaces on the load-slip characteristics of double-lap structural steel joints assembled with high-strength bolts. The 24 specimens were made from semi-killed plain carbon structural steel. The surfaces were either rolled, painted, metal sprayed, or sand blasted. The rolled surfaces were wire-brushed and cleaned mill scale. The painted surfaces were wire-brushed mill scale coated with red lead. The metals used in metal spraying included zinc, aluminum, and chrome nickel steel. It is concluded that protective coatings of sprayed metal may improve the coefficient of friction under static loading.

KEY WORDS: bolts; friction; joints; slippage; steel; testing

(153)

Cullimore, M. S. G.
TESTS ON AN ALUMINUM-ALLOY JOINT WITH PRE-TENSIONED BOLTS, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 48-51.

Nine tests were made on HE30-WP aluminum double-cover plate type butt joints. This joint design was selected to assure a tangential load between rubbing surfaces. Load at major slip was used to calculate the coefficient of friction, which was 0.140 for a joint with 1 bolt, 0.121 for 2 bolts, and 0.131 for 3 bolts. It is concluded that shot-blasting the faying surfaces creates satisfactory friction in aluminum alloy joints.

KEY WORDS: aluminum; bolts; friction; joints; slippage; testing

(154)

Johnson, L. G., Cannon, J. C., and Spooner, L. A.
JOINTS IN HIGH TENSILE, PRELOADED BOLTS-TESTS ON JOINTS DESIGNED TO DEVELOP FULL PLASTIC MOMENTS OF CONNECTED MEMBERS, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 52-62.

The effect of preloaded high-strength bolts on the plastic moment of the connected members of certain rigid joints was determined in six tests. The flange plates stiffen the parent joist and the section acts as a compound member. Preload is not guaranteed by tightening bolts to a given minimum torque. Maximum frictional grip is developed when the faying surfaces are not prevented from bedding closely together.

KEY WORDS: bolts; components; joints; moment; pretensioning

(155)

Gill, P. J.
NOTES ON THE LOAD CARRYING CHARACTERISTICS OF PRE-TENSIONED BOLTS-TENSIONED JOINTS, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 62-64.

The load-carrying characteristics of pretensioned bolts in tensioned joints are discussed. The bolt load does not increase unless the working load exceeds the bolt preload. When the working load exceeds the preload the increase in bolt load is very small. The increase in bolt load depends on the stiffnesses of the bolt and the bolted members, and the point at which the working load is applied. A few advantages of high preload are discussed.

KEY WORDS: bolt, pretensioned; joint, tensioned; load

(156)

Creasey, L. R.
THE USE OF HIGH STRENGTH BOLTS IN INDUSTRIAL AND COMMERCIAL BUILDINGS, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 2-10.

Discussed and illustrated are uses of high-strength bolts as structural fasteners, the design of high-strength bolt connections, and sample check tests on specimen connections and shop practice for the preparation and fabrication of such connections. The advantages in cost, ease of handling, and in simplicity of equipment and site organization of high strength bolts over traditional structural fasteners such as rivets, black bolts, and welds are also discussed.

KEY WORDS: bolts; joints; steel; structural engineering

(157)

Arch, W. H.
THE FIELD USE OF HIGH STRENGTH FRICTION GRIP BOLTS, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 10-13.

Explanations and solutions of various problems in the field use of high-strength friction-grip bolts are presented. Broadly discussed is the system adopted for use on a large power station. The reasons for using a calibrated pneumatic impact wrench are described.

KEY WORDS: bolts; friction; joints; steel

(158)

Berridge, P. S. A.
HIGH STRENGTH BOLTS IN RAILWAY BRIDGES AND STRUCTURES IN BRITAIN, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 14-24.

A descriptive discussion of the uses and advantages of high-strength bolts, torque limiting wrenches, torque multiplying wrenches, surface preparation of the plies, Prolong bolt, and Torshear bolts is presented. Brief notes on the turn-of-the-nut method of tightening high strength bolts using pneumatic wrenches and the application of high strength bolts to the site joints of plate girders and railway bridges are also included. The Prolong bolt has a longitudinal serrated extension which provides a built-in anchorage to take the reaction. The bolt was developed for applications where use of a geared torque-multiplying wrench required a reaction point on the adjacent structure. The Torshear bolt has a threaded portion which extends beyond a machined concentric groove outside the nut. When being tightened with a special wrench load is induced until the extension is sheared off in torsion.

KEY WORDS: bolts, joints, specifications, thread, torque

(159)

Higgins, T. R.
THE USE OF HIGH STRENGTH BOLTS IN THE UNITED STATES OF AMERICA, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 24-29.

A brief history of the development and use of the high-strength bolt is given, together with examples of its application in building and bridge construction in the U. S. Pretensioning and the means of achieving it with calibrated impact wrenches and the turn-of-the-nut method are discussed in detail. Research conducted at the University of Illinois, The Association of American Railroads, and Lehigh University is described as having shown that A325 bolts can be tightened past their yield strength without injury.

KEY WORDS: bolts; design; installing; joints; steel; structural engineering

(160)

Wolf, W.
THE USE OF HIGH STRENGTH BOLTS IN GERMANY, Jubilee Symposium on High Strength Bolts, The Institution of Structural Engineers, London, June 1959, pp. 30-35.

The history of the use of high-strength bolts in the construction of railway and highway bridges in Germany is traced. The advantages of high-strength bolts over other fasteners, the use of wrenches in tightening bolts, and the form of bridge construction adopted are reported.

KEY WORDS: bolt; bridges; joints; installing

(161)

Munse, W. H., and Chesson, E. , Jr.
SUMMARY-INVESTIGATION OF HIGH-TENSILE BOLTS AND BOLTED CONNECTIONS, University of Illinois, Urbana, November 1959.

Compiled are conclusions drawn by the staff at the University of Illinois from the 17 progress report summaries on the "Investigations on High-Tensile Bolts and Bolted Connections" for which research was started in 1947 for Project IV of the RCRBSJ, the Illinois Division of Highways, and the Department of Commerce-Bureau of Roads. The details of the tests, test specimens, and test results may be obtained from the original reports which are listed in the Table of Contents. A list of publications is also presented.

KEY WORDS: bolts; joints, bolted; RCRBSJ

(162)

Bendigo, R. A.
BOLT CALIBRATION STUDY, Fritz Engineering Laboratory Report No. 271.5, Lehigh University, Bethlehem, Pa., June 1959. (Summarized in CALIBRATION OF A325 BOLTS, by J. L. Rumpf and J. W. Fisher, Journal of the Structural Division, ASCE, Vol. 89, No. ST6, Proc. Paper No. 3731, December 1963, pp. 215-234.

This report contains a review of bolt calibration procedures and a discussion of the procedure used at Lehigh University, Bethlehem, Pennsylvania. The bolts used for the tests were regular head ASTM A325 high-strength bolts with quenched and tempered washers and heavy semi-finished nuts. 7/8", 1", and 1-1/8" bolts were used for direct tension calibration, torqued calibration, and load-unload-reload tests. The method used to induce the internal tension in the bolt in direct tension calibration and torqued calibration had no effect on the tension-elongation relationship in the elastic region. However, a very definite decrease in ultimate strength was apparent beyond the proportional limit for bolts torqued to obtain tension.

KEY WORDS: bolts; calibration; tension; testing; torque

(163)

Chesson, E., Jr., and Munse, W. H.
BEHAVIOR OF LARGE RIVETED AND BOLTED STRUCTURAL CONNECTIONS, Dept. of Civil Engineering, University of Illinois, Urbana, SRS No. 174, 1959. (Summarized in RIVETED AND BOLTED JOINTS:TRUSS-TYPE CONNECTIONS, by Chesson and Munse, Journal of the Structural Division, ASCE, Vol. 89, No. ST1, Proc. Paper No. 2412, February 1963, pp. 66-106).

Thirty truss-type specimens were tested to provide information on the distribution of load to gusset plates of double-plane built-up members and to determine the effect of the method of rivet hole preparation. The test variables included specimen configuration, method of hole preparation, and type and size of fasteners. The comparative behavior of the specimens is described. The formula $= PL/AE$ was satisfactory for use in elongation computations for truss members. Gusset plates were not always fully effective over their entire widths, and punched members were less efficient than drilled members. A comparison of predicted and actual efficiencies is made and the following items are recommended for consideration when designing tension members: (1) joint pattern, (2) method of hole manufacture, (3) distribution of area in the connection, and, (4) length of the connection. These items could be presented in a simple expression. If separate design stresses are specified for punched and for drilled members, a maximum of 90% gross area should be considered as effective in resisting tensile loads.

KEY WORDS: bolt; gusset plate; rivet; shear test; tension; trusses

(164)

Iron Age
STRONGER JOINTS CAN COST LESS, The Iron Age, July 2, 1959, pp. 72-76.

A descriptive article is presented on preload and strength of bolted joints. Graphs of the bolt tensile stress vs. torque are shown for different diameter steel bolts. A formula, T = f x D x L, where T is torque, f is the surface finish factor, D is nominal thread diameter in inches, and L is tension load in lbs., is given to predict required torque.

KEY WORDS: bolt; force, clamping; joint; pretensioning; torsion

(165)

Beano, S. Y., and Vasarhelyi, D. D.
THE EFFECT OF MISALIGNMENT OF HOLES ON THE BEHAVIOR OF BOLTED JOINTS, Dept. of Civil Engineering, University of Washington, Tenth Progress Report to RCRBSJ, August 1959. (Summarized in EFFECTS OF FABRICATION TECHNIQUES, Transactions, ASCE, Vol. 126, Part II, Paper No. 1973, 1961, pp. 764-796).

The results of 18 static tension tests of double lap tension splices are reported. Twelve of the joints had 1 row of 4 high-strength bolts. Two of the joints had 4 rows of 3 high-strength bolts. Eight of these specimens had one or more of the fasteners misaligned. In addition, 4 joints were connected by 1 row of 4 A141 steel rivets. All joints had red lead paint on the faying surfaces. The test results indicate that even severe misalignment has no significant effect on most of the characteristics of bolted joints. Neither the slip, elongation, joint efficiency, nor ultimate strength were significantly affected.

KEY WORDS: alignment; bolt; efficiency; joint; shear test; tension

(166)

Adler, R. C.
MORE ON BOLTS, Reader Comments, Engineering News-Record, August 6, 1959, p. 6.

5/8 in. bolts were tested in single and double shear, using 1/2 in. by 2 in. steel test pieces drilled with 11/16 in. holes. The bolts failed in single shear at an average load of 26,900 lb. and in double shear at 54,000 lb. Bearing stresses on the structural members, not bolt shear, are the limiting factors in design.

KEY WORDS: bearing strength; bolts; shear stress

(167)

Belford, R. B.
A REVIEW OF THE USE OF STRUCTURAL FASTENERS, Fasteners, Vol. 14, Nos. 2 and 3, Summer 1959, pp. 5-8.

A review of structural fasteners is presented in this article. The more than 100 million structural fasteners manufactured annually provide safe, dependable joints in structural applications. Riveting is the oldest known method of joining metal. The designer selects a rivet on the basis of load transference through shear on the rivets and bearing of the rivets against the walls of the rivet holes. Unfinished bolts are suitable for joining low-tonnage, light-framework structures. They should not be used for dynamic loading, stress reversal, or impact conditions. The high-strength bolt clamps a joint together so tightly that working loads are transferred from member to member by friction and not by shear and bearing. Various conditions for fastener use and installation are discussed in the article. Special structural fasteners are described and their basic uses are discussed.

KEY WORDS: bolts; bolt, unfinished; fasteners, special structural; rivets

(168)

Bendigo, R. A., and Rumpf, J. L.
CALIBRATION AND INSTALLATION OF HIGH-STRENGTH BOLTS, Fritz Engineering Laboratory Report No. 271.7, Lehigh University, Bethlehem, Pa., September 1959. (Revised in Fritz Engineering Laboratory Report No. 271.11, Lehigh University, 1960. Summarized in CALIBRATION OF A325 BOLTS, by J. L. Rumpf and J. W. Fisher, Journal of the Structural Division, ASCE, Vol. 89, No. ST6, Proc. Paper No. 3731, December 1963, pp. 215-234).

The results of 110 direct-tension and torqued-tension tests of regular head A325 bolts are reported. The major variables studied included grip, thread length between thread run-out and nut face, continuous vs. incremental torquing, and number of applications of a given nut rotation. The behavior of the bolts is examined and typical data are presented. Bolt calibration procedures are reviewed. For usual grips, the grip length was found to have no appreciable effect on the load-elongation characteristics when the length of thread under the nut was approximately the same. Nut rotations greater than one-half turn from snug give little additional clamping force. Decreasing the amount of exposed thread under the nut results in a decrease in the deformation capacity of the bolt.

KEY WORDS: bolts; joints; steel; structural engineering; testing

(169)

Lewitt, C. W., Chesson, E., Jr., and Munse, W. H.
PRELIMINARY REPORT ON RELAXATION STUDIES OF HIGH-STRENGTH BOLTS, Dept. of Civil Engineering, University of Illinois, October 1959.

Relaxation tests of high-strength bolts are reported. The turn-of-the-nut method produces bolt loads above the specified minimum. The load relaxations for bolt assemblies with and without washers are essentially the same and are on the order of 4% after one week, based on the "one minute" load. There is no obvious advantage in using the special head bolt, except that the large head simplifies assembly.

KEY WORDS: bolt; bolting; fatigue; relaxation test

(170)

Munse, W. H., and Chesson, E., Jr.
THE EFFECT OF METHOD OF TIGHTENING ON THE SLIP BEHAVIOR OF BOLTED JOINTS, Dept. of Civil Engineering, University of Illinois, Urbana, Illinois, November 1959.

Load-elongation relationships determined in tests of two bolts are presented graphically. Both were manually tightened to 5000 lb. One was tightened 1/2 turn more with a hand torque wrench, while the other was impacted the same amount. Both had the same total load. It is concluded that manually torqued and impacted bolts produce the same nominal coefficient of friction in joints if the bolts have the same tension load and if other factors are equal.

KEY WORDS: bolts; installing; joints; slippage; testing

(171)

Smith, C. R., and Zandman, F.
PHOTOSTRESS PLASTIC FOR MEASURING STRESS DISTRIBUTION AROUND RIVETS, Proceedings of Society for Experimental Stress Analysis, Vol. XVII, No. 1, 1959, pp. 23-24.

Presented is a very brief article reporting that photostress plastic has been used with apparent success in predicting fatigue life of plate material around rivets in small-scale tests.

KEY WORDS: fatigue life; plates; stress concentration

(172)

Engineering News-Record
WHICH WAY IS BETTER IN THE SHOP?, Engineering News-Record, January 14, 1960, pp. 53-54.

A fabricator, a bolt manufacturer, and a consulting engineering firm estimated after study that the substitution of high-strength bolts for rivets will increase a fabricating plant's production 66% without increases in labor force or plant size. The main advantage, reduced labor costs, and other advantages are listed and discussed.

KEY WORDS: bolts; fabrication; joints; rivets; steel

(173)

Lewitt, C. W., Chesson, E., Jr., and Munse, W. H.
STUDIES OF THE EFFECT OF WASHERS ON THE CLAMPING FORCE IN HIGH STRENGTH BOLTS, Dept. of Civil Engineering, University of Illinois, SRS No. 191, March 1960.

In 46 tests, washers affected neither the clamping force nor fatigue life of high strength A325 bolts connecting A7 steel.

KEY WORDS: bolt; fatigue; force, clamping; washers

(174)

Bendigo, R. A., and Rumpf, J. L.
STATIC TENSION TESTS OF LONG BOLTED JOINTS, Fritz Engineering Laboratory Report No. 271.8, Lehigh University, Bethlehem, Pa., February 1960. (Summarized in LONG BOLTED JOINTS, by Bendigo, R. A., Hanson, R. M., and Rumpf, J. L., Journal of the Structural Division, ASCE, Vol. 89, No. ST6, Proc. Paper 3727, December 1963, pp. 187-213).

Detailed are tests of 12 long A7 steel butt joints assembled with 7/8 in. A325 bolts installed by the turn-of-nut method. Bolts were installed in joints in two lines, each with 3 tp 10 bolts. Joints were proportioned so that the net plate area was always 10% greater than the bolt shear area. The major variable of the test series was joint length. Eight of the joints failed when one or more of the fasteners sheared. The remaining 4 joints failed when the plate fractured at the first line of bolts. The average shear strength of the bolts decreased with increasing joint length. With 10 fasteners in a line the average shear strength was approximately 75% at that of a single bolt. The load at which a joint slips into bearing has no relation to the ultimate strength. The slip coefficient determined experimentally from tests with dry mill scale surfaces was 0.45. When the mill scale was removed with a power tool, the slip coefficient was only about 0.25.

KEY WORDS: bolts; joints; slippage; steel; strength; structural engineering; testing

(175)

Estes, E. R., Jr.
RECENT DEVELOPMENTS IN THE USE OF HIGH STRENGTH BOLTS, Proceedings, National Engineering Conference, AISC, May 5-6, 1960, pp. 5-9.

The 1954 specification prepared by the Research Council on Riveted and Bolted Structural Joints for the use of A325 bolts in structural joints is discussed. The council approved a higher working stress value based on Council-sponsored tests on large bolted joints at Lehigh University. Tests conducted at the University of Illinois showed that bearing pressure for rivets in double or single shear has no effect on the strength of the connected parts, so long as this pressure does not exceed 2.25 times the tensile stress on the net area. A comparison of total costs of bolting vs. riveting made from time and motion studies sponsored by a bolt manufacturer in cooperation with a large fabricator show that savings of up to 17% may be possible.

KEY WORDS: bolts, A325; costs; economic factors; specifications

(176)

Ely, J. F.
TRUSS BRIDGE PROJECT AT NORTHWESTERN UNIVERSITY, Proceedings, AISC, May 5-6, 1960, pp. 10-16. (Also appeared as TRUSS BRIDGE PROJECT, Progress Report No. 5 to U. S. Army Engineer Research and Development Laboratories, Northwestern University Technological Institute, March 1, 1961).

At the time of writing, tests were still in progress on a half-scale steel truss bridge which can be loaded in varying patterns and amounts. The test program was divided into three phases: (1) performance of preliminary investigatory tests to establish successful methods of operation for the tests to follow, (2) establishment of a method of estimating the ultimate load of damaged end posts, and (3) determination of the effects of the floor system in truss action and of the stresses introduced by the erection of the floor system. The facility may be used to check new design concepts and to verify new analytical theories on a real bridge up through ultimate loads.

KEY WORDS: testing; truss bridge

(177)

Marcin, S. J.
LOAD DISTRIBUTION IN BOLTED JOINTS, Fritz Engineering Laboratory Report No. 271.13, Lehigh University, Bethlehem, Pa., June 1960. (Test results reported in LONG BOLTED JOINTS, by Bendigo, Hansen, and Rumpf, Journal of the Structural Division, ASCE, Vol. 89, No. ST6, Proc. Paper No. 3727, December 1963, pp. 187-213).

The load distribution among the bolts of a bolted double-lap tension splice at ultimate load was determined. The deflections of each bolt in 1 line of each of 4 test joints were measured. A single bolt from the same lot was subjected to increasing load increments in a shear jig and the deformations of the bolt at various known loads were measured. Plots of the deformed profile of the bolt were made and compared with the profiles of the bolts in the four test joints in order to determine the load that each bolt in the test joint was carrying.

KEY WORDS: bolts; distribution, load; steel; strength; structural engineering; testing

(178)

Thurlimann, B.
RESEARCH ON LARGE COMPACT JOINTS WITH HIGH STRENGTH STEEL BOLTS, Final Report Sixth Congress, IABSE, June 27-July 1960. (Additional details of the test results are given by Foreman, R. T., and Rumpf, J. L., STATIC TENSION TESTS OF COMPACT BOLTED JOINTS, Transactions, ASCE, Vol. 126, Part II, Paper No. 3125, 1961, pp. 228-254).

Tension-elongation curves of high-strength steel bolts, static tests on large compact bolted joints, and use of impact wrenches for inducing high initial bolt tension are comprehensively described. The 1960 American Specifications on high-strength bolts are reviewed.

KEY WORDS: bolt; elongation; joint; tension; wrench

(179)

Johnson, L. G., Cannon, J. C., and Spooner, L. A.
HIGH-TENSILE PRELOADED BOLTED JOINTS FOR DEVELOPMENT OF FULL PLASTIC MOMENTS, British Welding Journal, September 1960, pp. 560-569.

The results of 6 tests to investigate the use of high-tensile preloaded bolts for the development of full plastic moment of the connected members in certain rigid joints found in mild steel structures are reported. Flange plates have a stiffening effect on the parent joint. The half-torque, half-turn method of guaranteeing preload is better than the method of tightening bolts to give a minimum torque value. Maximum frictional grip between two members with bolts acting in equivalent shear is developed only when the contact surfaces are not prevented from bedding closely together.

KEY WORDS: bolt; joint; moment, plastic; slippage

(180)

Vasarhelyi, D. D., Taylor J. C., Vasishth, U. C., and Yaun, C. Y.
TEST OF A RIVETED PLATE GIRDER WITH A THIN WEB, Journal of the Structural Division, ASCE, Paper No. 2621, Vol. 86, No. ST10, October 1960, pp. 23-51. (Appeared as AN EXPERIMENTAL INVESTIGATION OF THE BEHAVIOR OF A RIVETED PLATE GIRDER WITH A THIN WEB, Dept. of Civil Engineering, University of Washington, Seattle, August 1959).

A full-size riveted plate girder with a web plate much thinner than that required under the conventional design specifications was tested. Methods for the determination of the critical buckling loads on the basis of theoretical formulae as well as from experimental results are outlined. A study is made of the change in the shear-carrying behavior of the web after buckling occurs and the ability of the web to withstand loads in excess of the critical buckling value. The mode of failure of the web is discussed. The behavior of the flanges of the girder was carefully observed. Particular emphasis is given to the stress distribution in the region where the cover plates are terminated.

KEY WORDS: failure; girder; plates; shear test; stress concentration; webs

(181)

Lind, H. H.
STORY OF THE RESEARCH COUNCIL AND DEVELOPMENT OF HIGH-STRENGTH BOLTING, Fasteners, Vol. 15, Nos. 2 and 3, Fall-Winter 1960, pp. 4-7.

This article discusses the formation of the Research Council and the development of high-strength bolting for structural steel. The Research Council on Riveted and Bolted Structural Joints has done much to further the acceptance of high-strength bolts by extensive research and field testing. From 1938 to 1947, intermittent research had been done on high-strength bolts. In 1947 the Research Council was formed with the financial backing of several sponsors, and a constitution was drawn up. From that time to the present, the Council has initiated extensive research in all facets of the application of high-strength bolts to structural joint conditions. Specifications have been established for the use of these bolts.

KEY WORDS: bolts; fatigue test; research; specifications; testing

(182)

Belford, B.
THE FIRST REPORT ON THE NEW HEAVY STRUCTURAL BOLT, Fasteners, Vol. 15, Nos. 2 and 3, Fall-Winter 1960, pp. 18-20.

The developments in the redesign of the high-strength bolt are presented. The new bolt is known as the heavy hexagon structural bolt. The width across flats on the new bolt head has been increased by 1/8-in. for all sizes. Under most circumstances, a washer is now required only under the bolt head or the nut, depending upon which is tightened. Also, the increased size of the bolt head requires the use of only one size wrench, for bolt and nut sizes are now identical. The thread length for the heavy bolt is shorter.

KEY WORDS: bolts; hexagonal-head bolts; hexagonal nuts; tolerances, manufacturing

(183)

Smith, A.M.
INTERFERENCE-BODY BOLTS, Fasteners, Vol. 15, Nos. 2 and 3, Fall-Winter 1960, p. 22.

The application and advantages of interference-body bolts are discussed. The new bolts have either knurled or ribbed shanks interrupted at intervals to allow the flow of excess metal into unoccupied areas. Interference-body bolts are easier to drive through badly misaligned holes than standard high-strength bolts.

KEY WORDS: bolts, interference-body; installing; joints

(184)

Fasteners
HIGH-STRENGTH BOLTS ARE STRONGER THAN EVER, Fasteners, Vol. 15, Nos. 2 and 3, Fall-Winter 1960, pp. 24-26.

Significant changes in joint assembly using ASTM A325 bolts are discussed. An increase in the required minimum bolt tension from 90% to 100% of bolt proof load is specified so that all properly tightened bolts will be preloaded into the plastic range. Also, all information on torque is deleted from present specifications because the hignly variable torque-tension relationship makes torque an unsatisfactory criterion for proper preloading. The "turn-of-nut" tightening procedure or the calibrated impact wrench to be used instead of the torque-tension relationship. The shank of the ASTM A325 nut and bolt assembly will fail before the threads will strip, so identification and replacement of failed bolts is easy.

KEY WORDS: bolts; load; tension; tension, minimum bolt; torque

(185)

Fasteners
WHY CHANGES WERE MADE IN HARDENED WASHERS, Fasteners, Vol. 15, Nos. 2 and 3, Fall-Winter 1960, pp. 27-28.

The reasons for two major changes in hardened washer use since 1960 are given. The circular washer has been made smaller because the larger area was not fully effective in distributing bolt load. One washer is now used instead of two, and it is used only at the bolt assembly end which is being turned. The number of washers was reduced because their primary purpose is to provide a non-galling surface under the element being turned.

KEY WORDS: joints; steel; washers

(186)

Ball, E. F.
TIGHTENING HIGH-STRENGTH BOLTS BY TURN-OF-NUT METHOD....SEVEN SIMPLE STEPS, Fasteners, Vol. 15, Nos. 2 and 3, Fall-Winter 1960, p. 29.

A tightening procedure for high-strength bolts is discussed. A seven-step outline followed by Bethlehem fabrication crews is as follows: (1) Fair-up holes with enough pins to maintain dimensions and plumbness of the structure and do not remove pins until bolts in balance of holes have been tightened; (2) Install bolts in the remaining holes; (3) Tighten enough bolts to snug to bring all of the connected parts firmly into contact. Snug condition is indicated when the wrench starts impacting solidly. For best results, tighten bolts progressively away from the fixed or rigid points to the free edges; (4) Tighten to snug each bolt not used to fit up; the fixed or rigid points to the free edges; (6) Replace pins with bolts, tighten to snug and then tighten prescribed turn; and (7) Mark completed joint with identifying symbol. The results of some of these operations are discussed.

KEY WORDS: bolting; bolts; procedure; tension

(187)

Estes, E. R., Jr.
THE ADVANTAGES OF DESIGNING STRUCTURAL STEEL CONNECTIONS USING A325 BOLTS, Fasteners, Vol. 15, Nos. 2 and 3, Fall-Winter 1960, pp. 30-32.

The new ASTM A325 bolt specifications have encouraged the use of bolts in connections formerly fastener with rivets. Because of the high strength of the A325 bolt, it can be used in smaller quantities than the rivets it supersedes. A basic table of allowable stresses for tension, friction-type shear, and gearing-type shear is included. Sample calculations are presented for a connection in which the usual rivets are replaced by high-strength bolts. A similar example is given for a moment connection.

KEY WORDS: bolts; design; joints; steel; structural engineering

(188)

Graves, F. E.
HIGH-STRENGTH BOLTING MOVES INTO FABRICATION SHOPS, Fasteners, Vol. 15, Nos. 2 and 3, Fall-Winter 1960, pp. 33-37.

High-strength bolting, already proven superior in the field, is discussed as a substitute for riveting in shop fabrication. A shop study was conducted on twelve trusses which were designed for shop riveting rather than bolting. Half were riveted and the remainder were bolted. The results showed that with high-strength bolted connections there is more output for a given labor force and production facility, a definite decrease in fit-up and alignment time, and a saving of material and operations, all of which cut costs. Also, design economy and greater plant flexibility indicate that high-strength bolting has definite advantages over riveting in the shop.

KEY WORDS: bolting; costs; fabrication; force, equipment; force, labor; riveting; time study

(189)

Fasteners
FOUR HUNDRED THOUSAND HIGH-STRENGTH BOLTS, Fasteners, Vol. 15, Nos. 2 and 3, Fall-Winter, 1960, pp. 38-99.

The city of Detroit built a 54-million dollar exhibit and convention center. The use of 400,000 high-strength bolts speeded construction so that all steel fabrication was completed 90 days ahead of schedule. The high-strength bolts were used in conjunction with rivets and machine bolts for minor struts and gussets. Each bolt was properly torqued with a calibrated impact wrench.

KEY WORDS: bolts; fabrication; structural steel; wrench

(190)

Rumpf, J. L.
THE ULTIMATE STRENGTH OF BOLTED CONNECTIONS, Ph. D. Dissertation, Lehigh University, Bethlehem, Pa., September 1960. (Fritz Laboratory Report No. 271.14).

A theoretical solution for the unequal distribution of load among the bolts of a double shear splice under static axial load is developed. Attention was centered on the region between slip load and ultimate load in which the bolts and the plates are deforming in a non-linear manner. Determination of the unknown bolt forces was accomplished by the solution of an equilibrium equation and a set of compatibility equations. The non-linear relationships of force to deformation were determined experimentally by tests of representative portions of plate and of single bolts. The solution has been used to predict the ultimate strength of the bolts in connections with 3 to 10 fasteners in a line. The theoretical solution was verified by comparing the results with tests of 8 full-size connections. A limited study made of the effect of variations in the tension-shear ratio indicated that a surplus of plate material will reduce plate strains and will result in a more uniform distribution of load among the fasteners.

KEY WORDS: bolts; joints; steel; strength; structural engineering; tensile strength

(191)

Vasishth, U. C.
A STUDY OF THE BEHAVIOR OF RIVETS, The Trend of Engineering, The Engineering Experiment Station, University of Washington, October 1960.

Such aspects of the behavior of rivets and plates of girders subjected to point loads as how rivets fill the holes and the location of gaps between the shanks of rivets and the rivet holes are discussed. In manufacturing processes, gaps are liable to occur along the shank of the rivet. The behavior of riveted joints is similar to that of bolted joints before any major slip occurs. In both joints the friction resulting from the clamping force influences the action of the joint. An attempt is made to estimate the clamping force of a riveted joint. The clamping force relieves much of the stress on the rivet by developing friction in the plates. It was found that for up to 2.13 times the design load, plastic deformation does not take place in either the end rivets or the plates.

KEY WORDS: force, clamping; joint; plate; rivet; stresses

(192)

Heap, W. J., and Gill, P. J.
SLIPPING TESTS ON BOLTED JOINTS WITH VARYING CLAMPING FORCES, Unpublished Report No. 457, G. K. N. Group Research Laboratory, London, 1960.

Tests were carried out on simple single-bolt, double-lap joints to investigate the variation of slipping load with varying clamping forces on the slipping surfaces. The faying surfaces were wire-brushed to remove mill scale. The relationship between slipping load and clamping force is approximately linear. When an external tensile load is applied to a joint, the reduction in interface clamping force is equal to the applied external tensile force. The slipping load is nominally proportional to tightening torque. The coefficient of friction varied from 0.4 to 0.7 in these tests.

KEY WORDS: bolt; force, clamping; joint; slippage

(193)

Viner, J. G., Dineen, R. L., Chesson, E., Jr., and Munse, W. H.
A STUDY OF THE BEHAVIOR OF NUTS FOR USE WITH HIGH-STRENGTH BOLTS, Dept. of Civil Engineering, University of Illinois, Urbana, SRS No. 212, April 1961.

The behavior of heavy, finished thick, and finished nuts over a range of hardness values when torqued to failure using ASTM A325 high strength bolts was investigated in tests of 700 3/4 in., 7/8 in., and 1 in. bolt assemblies. Some bolts and nuts were also tested in direct tension to compare static strength with torqued strength. Bolts having nuts of the heavy, finished thick, and finished type of proper hardness develop proof loads at 1/2 turn from snug and if loaded in tension to failure will fail through the bolt threads.

KEY WORDS: bolts; nuts; strength, static; strength, torqued

(194)

Sherbourne, A. N.
BOLTED BEAM TO COLUMN CONNECTIONS, The Structural Engineer, Vol. 39, No. 6, London, June 1961, pp. 203-210.

Five tests were made on mild steel specimens, each in the form of a plate welded to the end of a beam and fastened to the flanges of a column with preloaded high-strength bolts. Various combinations of end plate and column stiffeners were tested. For the connection to be most efficient, the component parts must be proportioned so that they all reach the required strength and yield simultaneously. General conclusions are drawn regarding the plastic design of many types of bolted connections.

KEY WORDS: analyzing; bolts; joints; steel; structural engineering; testing

(195)

Jones, R., and Baker, A. R.
HIGH-STRENGTH BOLTS-THE BEHAVIOR OF STRUCTURAL CONNECTIONS USING HIGH STRENGTH BOLTS STRESSED BEYOND THEIR PROOF STRESS, The Structural Engineer, Vol. 19, No. 7, London, July 1961, pp. 228-234.

The effect of bolt preloads above 20% of proofload on the structural efficiency and ultimate strength of a joint was investigated in tests of 8 double-lap tensile butt joints fastened with high-strength bolts. In these joints, bolt preload raises the yield point of the joint without affecting the ultimate strength of the plates.

KEY WORDS: bolts; joints; slippage; steel; strength; testing

(196)

Diemer, C. P.
THE RIVET....USE IT RIGHT AND YOU CAN'T BEAT IT, Fasteners, Vol. 16, Nos. 1 and 2, Spring-Summer 1961, pp. 3-5.

The author discusses rivets and their development. Rivets are one of the oldest and most dependable methods for fastening structural steel. The full shear strength attained from a filled rivet hole and the high tensile prestress in a cooled hot rivet are not affected by stress reversals or other forces. Rivets cost 1/3 as much as high-strength bolts, and overall economy results from their use. However, the labor saves in field erection by using high-strength bolts may drop total costs below those of riveting. Shop erection makes use of the low cost and versatility of rivets.

KEY WORDS: bolts; construction, shop; fabrication; rivet; structural steel

(197)

Hanneman, W. M.
HOW PLATED FINISHES AFFECT BOLT TIGHTENING, Fasteners, Vol. 16, Nos. 1 and 2, Spring-Summer 1961, pp. 7-11.

The effects of different finishes on the torque tightening of threaded fasteners are presented. Plated and plain oiled finishes were tested in various combinations of nuts, bolts, and washers, and results are graphed and tabulated. A wide range of results is described.

KEY WORDS: bolting; finishes, plated; torque

(198)

Hansen, R. M.
THE EFFECT OF FASTENER PITCH IN LONG STRUCTURAL JOINTS, Fritz Engineering Laboratory Report No. 271.17, Lehigh University, Bethlehem, Pa., May 1961.

The results of an analytical study of ten hypothetical joints is presented. The hypothetical joints were A7 steel plates fastened with A141 steel rivets or A325 bolts. The bolted joints had nine fasteners in a line and the riveted joints thirteen fasteners in a line. For a given number of bolts or rivets in a line, the ultimate strength of the connections decreases as the pitch increases.

KEY WORDS: bolts; joints; rivets; steel; structural engineering; tensile strength; testing

(199)

Hansen, R. M., and Rumpf, J. L.
FURTHER STATIC TENSION TESTS OF LONG BOLTED JOINTS, Fritz Engineering Laboratory Report No. 271.15, Lehigh University, Bethlehem, Pa., October 1961. (Summarized in LONG BOLTED JOINTS, by Bendigo, Hansen, and Rumpf, Journal of the Structural Division, ASCE, Vol. 89, No. ST6, Proc. Paper No. 3727, December 1963, pp. 187-213).

The results of tests of 4 large A7 steel butt joints connected with 7/8 in. A325 bolts are reported. The bolts were arranged in two lines of from 10 to 16 bolts each. The joints were proportioned so that the net plate area was always 10% greater than the bolt shear area. The major variable was joint length. The longitudinal distance between fasteners was 3.5 in. except for one joint in which it was 2.63 in. Failure occurred in all cases with the shearing or "unbuttoning" of one or more end fasteners. The average bolt shear strength at failure for the joint with 16 bolts in line was about 60% of the shear strength of a single bolt. Pitch significantly affected connection behavior. The total joint length, not the number of fasteners, was the most important variable in determining average shear strength. The dry mill scale faying surfaces yielded slip coefficients between 0.31 and 0.46.

KEY WORDS: bolts; joints; slippage; steel; strength; structural engineering; testing

(200)

Foreman, R. T., and Rumpf, J. L.
STATIC TENSION TESTS OF COMPACT BOLTED JOINTS, Transactions, ASCE, Vol. 126, Part II, Paper No. 3125, 1961, pp. 228-254. (Appeared in Journal of the Structural Division, ASCE, Vol. 86, No. ST6, Proc. Paper 2523, June 1960, pp. 73-99. First appeared as Fritz Engineering Laboratory Report No. 271.6, Lehigh University, Bethlehem, Pa., 1959).

Static tension tests of 8 large A7 steel butt joints fastened with A325 bolts arranged in compact patterns and installed by the turn-of-nut method are described. One large riveted joint was tested to provide comparative data. Six of the joints were connected with 7/8 in. A325 bolts with 3 to 6 fasteners in a line. Five of these joints had 5 lines of fasteners and 1 joint had 6 lines of fasteners. The other two joints were connected by 1 in. and 1-1/8 in. A325 bolts respectively. The 1 in. bolts were arranged in a 4 x 4 pattern and the 1-1/8 in. bolts were arranged in a 4 x 3 pattern. The specimens were fabricated at various tension shear ratios (the ratio of the tensile stress on the net section of the plate to the shear stress on the fasteners). The joints were pulled to failure under static loads. The tests indicated that simultaneous failure of the A325 bolts and the plate would occur when the net plate area was approximately 10% greater than the bolt shear area. Major slip occurred at nominal bolt shear stresses 75 to 140% in excess of normal working stress. The average slip coefficient was approximately 0.4.

KEY WORDS: bolts; joints; rivets; slippage; steel; strength; structural engineering

(201)

Ruble, E. J.
COUNCIL RESEARCH, Transactions, ASCE, Vol. 126, Part II, Paper No. 3241, 1961, pp. 694-699. (Appeared first as RIVET AND BOLT COUNCIL RESEARCH, Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paper 1969, March 1959, pp. 1-6).

A brief history of, and the various research projects undertaken by the Research Council on Riveted and Bolted Structural Joints are outlined. A list is given of the Council's principal financial sponsors and the Universities where research is being conducted. A complete bibliography of the reports published by the Council is included.

KEY WORDS: bolt; joint; research; rivet

(202)

Munse, W. H., Petersen, K. S., and Chesson, E., Jr.
STRENGTH IN TENSION, Transactions, ASCE, Vol. 126, Part II, Paper No. 3241, 1961, pp. 700-728. (Appeared in Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paper 1970, March 1959, pp. 7-28. Original paper appeared as STATIC TENSION TESTS OF RIVETS AND HIGH-STRENGTH BOLTS IN STRUCTURAL CONNECTIONS, Dept. of Civil Engineering, University of Illinois, SRS No. 124, November 1956).

The behavior of fasteners in tension-type structural connections assembled with ASTM A325 bolts or with rivets of A141 steel is studied and discussed. Twelve riveted connections and 16 bolted connections were tested. The test specimens consisted of two wide-flange tees with the flanges butted together. Four variables were studied: (1) the number of lines of fasteners (either 2 or 4), (2) the flange width, (3) the flange thickness, and (4) the type of fasteners. The tee sections were cut from 24WF130, 30WF210, and 36WF300 sections. The efficiency of the joint is about the same for both types of fasteners. Members with 8 fasteners in 4 lines were generally less efficient but stronger than similar members with 4 fasteners in 2 lines. The stiffness of both the flanges and the fill plates affects the efficiency of the members.

KEY WORDS: bolt; force, clamping; rivet; testing

(203)

Douty, R. T.
DISCUSSION (ON "STRENGTH IN TENSION" by Munse, Petersen, and Chesson), Transactions, ASCE, Vol. 126, Part II, 1961, pp. 719-726.

This is a discussion of Abstract 203 "Strength in Tension" by W. H. Munse, K. S. Petersen, and E. Chesson. Mr. Douty performed tests similar to those described in "Strength in Tension" except that high-strength bolts were used in one line on either side of the web of the tee. The results were used to substantiate a theoretical investigation of the tension in the bolts throughout the elastic, plastic, and strain-hardening range of the flange. This analysis provides a means for designing the connection so that its plastic moment capacity is equal to or larger than that of the connected member. It is possible to use a bolted connection to develop the plastic moment capacity of a section and to use plastic analysis predict the tension in the fasteners. The bolt tension is a function of flange rigidity, edge distance, and reduced section due to fastener holes.

KEY WORDS: bolts; fasteners; force, clamping; rivet

(204)

Penman, W. R., and Ball, E. F.
DISCUSSION (ON "STRENGTH IN TENSION" by Munse, Petersen, and Chesson), Transactions, ASCE, Vol. 126, Part II, 1961, pp. 726-727.

The discussers regard as only partially correct the statement of W. H. Munse, K. S. Petersen, and E. Chesson, Jr., in their paper "Strength in Tension" (Abstract 203) that certain design specifications prohibit the use of structural connections to resist tensile loads. At the time the paper was discussed there were only a few specifications which did not sanction the use of rivets or bolts in tension-resisting connections. Bolts are used in tension not only in multi-story buildings but also as flange fasteners and studs in high-temperature piping systems and as cylinder-head studs in engines. With regard to the statement that the cross sectional area of a driven 3/4 in. diameter rivet is 0.518 sq. in. as compared to stress area of 0.334 sq. in., the writers suggests a nominal area of 0.442 sq. in. for a 3/4 in. rivet for design considerations.

KEY WORDS: bolts; joints; nuts; rivet

(205)

Munse, W. H., Petersen, K. S., and Chesson, E., Jr.
COMMENTS (ON THE DISCUSSION OF THEIR PAPER "STRENGTH IN TENSION"), Transactions, ASCE, Vol. 126, Part II, 1961, p. 727.

The comments of the authors of "Strength in Tension" (Abstract 203) on its discussion by R. T. Douty, W. R. Penman, and E. F. Ball are presented. Although the discussions maintain that stripping failures are uncommon this was not the case before the proof loads for heavy hexagon series nuts were increased in ASTM specifications (at the request of the Research Council on Riveted and Bolted Structural Joints because of results of laboratory studies). The authors reiterate that there were still a few specifications such as AASHO and AREA specifications which did not sanction the use of bolts or rivets in tension. The authors show that the nominal cross-sectional area of a 3/4 inch rivet is 0.500 sq. in. and not 0.442 as suggested by Mssrs., Penman and Ball and that the value of 0.518 sq. in. as originally recommended by the authors results only in 4% error.

KEY WORDS: bolt; nuts; rivet

(206)

Bell, W. G., Chesson, E., Jr., and Munse, W. H.
BEHAVIOR OF RIVETED AND BOLTED BEAM-TO-COLUMN CONNECTIONS, Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paper 1971, March 1959, pp. 29-50. (Appeared as STATIC TESTS OF STANDARD RIVETED AND BOLTED BEAM-TO-COLUMN CONNECTIONS, Dept. of Civil Engineering, University of Illinois, Urbana, SRS No. 146, January 1958).

Four members with standard connections consisting of angles fastened to the beam web and column flange were tested. Three of the test specimens were assembled with rivets and high-strength bolts and tested at different ratios of moment to shear. The fourth specimen was assembled entirely with rivets to provide a comparison of the effect of the type of fasteners upon the general behavior of the connections and to permit a correlation with previous tests. As the connections were loaded to failure a study was made of the moment-rotation characteristics, moment-resisting capacity, the position of the center of rotation, the deflection-rotation characteristics, the deformation of the fasteners, the separation of the column flanges, and the slip and shear deformation. These connections, although assumed for design purposes to behave as simple supports, actually do provide some end restraint. The restraint provided by the connections was increased slightly by the use of high-strength bolts in place of rivets to fasten the connection angles to the column flanges.

KEY WORDS: bolts; joints; rivet; testing

(207)

Hansen, N. G.
FATIGUE TESTS OF JOINTS OF HIGH-STRENGTH STEEL, Transactions, ASCE, Vol. 126, Part II, Paper No. 3241, 1961, pp. 750-763. (Appeared in Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paper 1972, March 1959, pp. 51-68).

Tests were performed to determine how much increase in cyclic load can be allowed when steels other than A7 steel are used in structures. Rivets of carbon steel (A141) and manganese steel (A195), and A325 high-strength bolts were used as fasteners. The joints were tested in direct tension with the loading cycle varying from zero to maximum. Two test programs are reported. In the first program 16 different steels were tested in the form of plates with single holes. The effect of the stress concentration was assessed by comparison of tests of similar plate specimens holes. Over 100 tests were made. A total of 210 double-lap joints were tested in fatigue in the second program. The specimens were fastened with rivets or bolts. Ten different steels were considered, including 7 from the first program. Joints which have high clamping force have high fatigue strength, and joints connected with high-strength bolts have higher fatigue strength than those connected with rivets.

KEY WORDS: bolt; fastener; fatigue; force, clamping; rivet

(208)

Vasarhelyi, D. D., Beano, S. Y., Madison, R. B., Lu, Z. A., and Vasishth, U. C.
EFFECTS OF FABRICATION TECHNIQUES, Transactions, ASCE, Vol. 126, Part VI, Paper No. 1973, 1961, pp. 764-796. (Appeared in Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paper 1973, March 1959. Also appeared as Summary Report No. 2, Dept. of Civil Engineering, University of Washington, December 1957).

This report summarizes Progress Reports 1-9 of the University of Washington to the RCRBSJ. The effects of punched holes, misalignment, and painted faying surfaces were investigated in 19 tests of double-lap joints. Fifteen joints were connected by twelve 3/4 in. A325 bolts and 4 were connected by 4 7/8 in. A325 bolts. Misalignment and painted faying surfaces have little influence on the joint efficiency. The punching of holes influenced the efficiency to the same extent for both riveted and bolted joints. The effect of the one-turn-of-the-nut tightening method upon slip and efficiency was investigated in tests on 4 large joints and 26 4-bolt joints. The method provided high clamping forces. Both load partition and joint efficiency were the same as for joints with bolts tightened to the minimum tension. An analysis was made of the nominal coefficient of friction in joints using the results of tests conducted at Northwestern, Illinois, and Washington Universities. The most critical factor influencing the coefficient of friction is the condition of the faying surface. Among the factors reducing the coefficient of friction are increasing bolt tension, decreasing tension-shear ratio, increasing size of joint, and increasing number of bolts.

KEY WORDS: bolts; friction; holes, misaligned; holes, punched; installing; joints; surfaces, faying; temperature; testing

(209)

Ball, E. F., and Higgins, J. J.
INSTALLATION AND TIGHTENING OF BOLTS, Transactions, ASCE, Vol. 126, Part II, Paper No. 3241, 1961, pp. 797-807. (Appeared in Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paer 1947, March 1959, pp. 117-132).

The procedures which have been used by Bethlehem Steel Co. to ensure that high-strength bolts are installed and tightened to produce the minimum bolt tension required by specifications are described. The studies and tests that were made to develop a safe, practical, and economical method of bolt tightening are also presented. Included are a brief history of the use of the high-strength bolt as a fastener for structural steel joints and instructions given to erectors by Bethlehem Steel Co. for tightening high-strength bolts.

KEY WORDS: bolt; fastener; procedure; tension

(210)

Zweig, B. A.
Discussion on "INSTALLATION AND TIGHTENING OF BOLTS", by E. F. Ball, and J. J. Higgins, Transactions, ASCE, Vol. 126, Part II, 1961, p. 807.

The paper "Installation and Tightening of Bolts" (Abstract 26) is discussed. Mr. Zweig observed the erection of the National Bank Building in Detroit, Michigan, and the Plymouth Assembly plant in St. Louis, Mo., where the method described in the above paper proved efficient. But the tightening of the fitting-up-bolt, as suggested in the procedure, is not as rigidly and rationally controlled as that of the other bolts. The writer therefore suggests that a simple method be devised to alleviate this shortcoming.

KEY WORDS: bolts; force, clamping; installing; nuts

(211)

Zar, M.
Discussion on INSTALLATION AND TIGHTENING BOLTS, by E. F. Ball, and J. J. Higgins, Transactions, ASCE, Vol. 126, Part II, 1961, p. 808.

Mr. Zar notes in his discussion of Abstract 210 that bolts will always be above minimum tension when nut are tightened 1/2 turn beyond snug position. However, because many experienced workmen rely on their judgement and fail to observe the turn-of-nut procedure, a thorough inspection of the work is usually necessary. Instruction No. 6 in the authors paper which reads, "check the tightness of each fit-up bolt with impact wrench", is vague because the meaning of check is unclear. The original fitting-up bolts may lose tension as other bolts are tightened.

KEY WORDS: bolts; installing; joints; fabrication

(212)

Munse, W. H.
Discussion on "INSTALLATION AND TIGHTENING OF BOLTS", by Ball and Higgins, Transactions, ASCE, Vol. 126, Part II, 1961, pp. 808-809.

The relationship between torque and clamping force is inconsistent. Tests indicate that the turn-of-nut method preloads bolts more accurately than the torque method. But even here a procedure should be laid down to provide a clamping force which exceeds slightly but not excessively the initial yield elongation of the bolt material. The procedure described by the authors of Abstract 210 comes close to this. Although the half-turn method appears to be simple, repeated application of this method may cause the bolt assembly to fail.

KEY WORDS: bolt; force, clamping; procedure

(213)

Archibald, R.
Discussion on "INSTALLATION AND TIGHTENING OF BOLTS", by Ball, and Higgins, Transactions, ASCE, Vol. 126, Part II, 1961, p. 809.

The authors' instructions for tightening high strength bolts (Abstract 210) may be universally accepted. However, instruction No. 6 is vague. After the joint has been completed, the fitting-up bolts should be loosened and tightened in the same manner as the other bolts to ensure that the nuts have been turned 1/2 or 3/4 turn beyond snug position.

KEY WORDS: bolt; bolting; fastener; force, clamping; instructions

(214)

Ball, E. F., and Higgins, J. J.
"INSTALLATION AND TIGHTENING OF BOLTS", Transactions, ASCE, Vol. 126, Part II, 1961, pp. 809-810.

The doubt expressed by Zweig, Zar, and Archibald that the turn-of-nut method may not control the tightening of the fitting up bolts as rigidly as that of the other bolts is unjustified. In field testing of completed joints with calibrated torque wrenches it was found that the tension in the bolts used for fitting up is the same as the tension in the other bolts. This was also found to be true in tests at Lehigh University, Bethlehem, Pa. Better results can be obtained by using a large number of bolts in a joint for fitting-up purposes. A thorough inspection of the joint is desirable and this can be done only with the calibrated-torque-wrench. Tests show that bolts can be re-used five times.

KEY WORDS: bolts; fastener; procedure; strength

(215)

Kinney, J. W.
HIGH-STRENGTH BOLTS ON MACKINAC BRIDGE, Transactions, ASCE, Vol. 126, Part II, Paper No. 3241, 1961, pp. 881-820. (Appeared as EXPERIENCE WITH HIGH-STRENGTH BOLTS IN THE MACKINAC BRIDGE, Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paper 1975, March 1959, pp. 133-144).

A brief description of the Mackinac Bridge project and details of the particular applications of bolted connections are given. The procedure for bolting and inspection as developed for the project is outlined. Some of the more common troubles are described and illustrated. Among the conclusions drawn from experience are: (1) considerably more time must be spent on bolt inspection than on rivet inspection, (2) the trend toward bolting will continue, and (3) upper limits should be set for allowable torque.

KEY WORDS: bolts; construction; joint; structural engineering

(216)

Dlugosz, S. E., and Fisher, J. W.
CALIBRATION STUDY OF HEAVY HEAD A325 BOLTS, Fritz Engineering Laboratory Report No. 271.21, Lehigh University, Bethlehem, Pa., February 1962. (Summarized in CALIBRATION OF A325 BOLTS, Journal of the Structural Division, ASCE, Vol. 89, No. ST6, Proc. Paper 3731, December 1963, pp. 215-234).

The results of 42 direct-tension and torqued-tension tests of 7/8 in. heavy-head A325 bolts with short thread length are presented. The test results are compared with the results of studies of regular-head bolts with longer thread lengths. Head type was not a significant factor in bolt behavior. Decreasing the amount of exposed thread under the nut resulted in a decrease in the deformation capacity of the bolt. The 1/2 turn-of-nut procedure produced initial bolt tensions 30% in excess of the minimum tension requirements. The rotational factor of safety against twisting off decreased with a decrease in exposed thread length. Grip length had no appreciable effect on the load-elongation characteristics of the bolt.

KEY WORDS: bolts; joints; steel; structural engineering; testing

(217)

Knoell, A. C., Chesson, E., Jr., and Munse, W. H.
FATIGUE BEHAVIOR OF BOLTED JOINTS ASSEMBLED WITHOUT WASHERS, Dept. of Civil Engineering, University of Illinois, SRS No. 242, February 1962.

The behavior of bolted joints subjected to fatigue tests is explained. Fatigue life of bolted joints does not change much as a result of omitting the washers if the bolts are tightened to at least minimum specified tension. Most of the loss in bolt tension occurs in the first few cycles of loading whether or not hardened washers are used.

KEY WORDS: bolt; fatigue; force, clamping; joint; slippage; washers

(218)

Radzimovsky, E., and Kasuba, R.
BENDING STRESSES IN THE BOLTS OF A BOLTED ASSEMBLY, Paper No. 731, Society for Experimental Stress Analysis, May 1962.

An analysis of the effects of flexural deformation on bolted assemblies is presented. The deformity of the connected members is the main factor influencing the bending stresses in the bolt. In certain connections these bending stresses considerably influence the strength and reliability of the assembly. Assembly clearance is a factor upon which the flexural deformation of the individual members and bending stresses in the bolts greatly depend. Pre-tightening load was found to have little influence on the bending stresses, while reduction of bolt width in the plane of bending produced a reduction in the bending stress.

KEY WORDS: assemblies; bending; bolt; stresses

(219)

Chu, T. Y.
THE EFFECT OF BEARING STRESSES ON THE FATIGUE STRENGTH OF A STRUCTURAL JOINT, M. S. Thesis, University of Kansas, Lawrence, Kansas, May 1962.

The effects of bearing stresses on the fatigue strength of a structural joint are discussed. The endurance limit of joint with no clamping force decreases linearly with increase in bearing stress. The endurance limit of a bolted joint with enough clamping force depends in essence on the material properties of connections and this limit approaches the yield point of the material for all geometries. Geometry changes the strength of S-Series joint, clamping force eliminates this change. A relationship could be developed between the plate thickness and stress concentration. The endurance limit in bolted joints is given by $S_e = N_x (B.R)^{-n}$.

KEY WORDS: bearing; bolt; fatigue; joint; rivet; stresses

(220)

Dlugosz, S. E.
STATIC TENSION TESTS OF LONG RIVETED JOINTS, Fritz Engineering Laboratory No. 271.20, Lehigh University, Bethlehem, Pa., June 1962. (Summarized in LONG BOLTED JOINTS, Journal of the Structural Division, ASCE, Vol. 89, No. ST6, Proc. Paper 3727, December 1963, pp. 187-213).

The results of an experimental and theoretical study of 3 long A7 steel butt joints assembled with 7/8 in. A141 steel rivets are reported. The net plate area was 75% of the rivet shear area. Joint length was the major test variable. The specimens had 2 lines of rivets with 7, 10, and 13 rivets in a line. The end rivets sheared before all rivets could develop their full shearing strength. The average shear strength of the joint with 7 rivets in a line was 84% of the shear strength of a single rivet and was 74% for the joint with 13 rivets in a line. Slip occurred in all 3 joints.

KEY WORDS: joints; rivets; slippage; steel; strength; structural engineering; testing

(221)

Yeakel, W. R.
65,000 NEW HEAVY HEAD HIGH-STRENGTH BOLTS WERE USED IN THE ASSEMBLY OF THE SPACE NEEDLE FOR THE 1962 SEATTLE WORLD'S FAIR, Fasteners, Vol. 17, No. 2, Summer 1962, pp. 3-5.

A short treatise on the construction of the Space Needle at the Seattle World's Fair is presented. The 600 ft. structure is entirely of high-strength bolted and welded construction. The 3 legs are curved to almost meet at a height of 373 feet and then flare out at the top to support a revolving restaurant. The use of high-strength bolts allowed the steelwork to be completed in five months and also allowed the actual conception of the design. The Needle is designed to withstand twice the seismic load required by the building code and one-and-one-half the maximum wind load ever recorded in that area.

KEY WORDS: bolts, heavy head; construction; design; fabrication ; structural engineering

(222)

Hotchkiss, J. G.
SINEWS OF CONSTRUCTION, Fasteners, Vol. 17, No. 2, Summer 1962, pp. 12-15.

A review of new provisions for fasteners in the AISC Specification for the Design, Fabrication, and Erection of structural steel for buildings is presented. Comparisons are made among shear and tension design loads for rivets, A325 high-strength bolt, and the new A354 high-strength bolt. Combined shear and tension are related by a graph, and fatigue is discussed.

KEY WORDS: bolts; construction; design; fatigue; fillers; rivets; shear test; strength; stresses; structural steel; tension

(223)

Bendigo, R. A., Fisher, J. W., and Rumpf, J. L.
STATIC TENSION TESTS OF BOLTED LAP JOINTS, Fritz Engineering Laboratory Report No. 271.9, Lehigh University, Bethlehem, Pa., August 1962. (Summarized in LONG BOLTED JOINTS, by Bendigo, Hansen, and Rumpf, Journal of the Structural Division, ASCE, Vol. 89, No. ST6, Proc. Paper 3727, December 1963, pp. 187-213).

The results of tests of 4 large lap splices connected by 2 lines of 7/8 in. A325 bolts are reported. The major test variable was joint length. Rotation of the connections due to eccentricity was restrained by an external bracing system. Failure occurred with the shearing of 1 or more of the fasteners. The behavior of the lap splices is compared with that of the double-shear tension splices. A lap splice can be considered equivalent to half of a double-shear splice of similar dimensions and materials, and a similar number of bolts. The joints had faying surfaces with the mill scale removed with a power tool. The average slip coefficient was 0.27.

KEY WORDS: bolts; joints; slippage; steel; strength; structural engineering; testing

(224)

Belford, R. B.
NEW SPECIFICATIONS FOR HIGH-STRENGTH BOLTING, Fasteners, Vol. 17, No. 3, Fall 1962, pp. 6-10.

New specifications for high-strength bolting as approved by the Research Council on Riveted and Bolted Structural Joints in March 1962 are presented. Washers are no longer required when heavy hexagon-head structural bolts are tightened by the turn-of-nut method. Semi-finished hexagon bolts have been dropped from the specification because the Council has decided to recommend only the best bolt types. Special fasteners can be used if they meet the chemical and dimensional rquirements of the specification.

KEY WORDS: bolting; hexagonal-head bolts; shear test; specifications; tension

(225)

Diemer, J. A., Hunt, E. M., and Hanna, J. C.
THE REAL STRENGTH OF RIVETS, Fasteners, Vol. 17, No. 4, Winter 1962-1963, pp. 6-10.

The physical design, manufacturing specification, and driving method for a new lower-cost rivet are proposed. The rivet itself has a new shape, and the finished head will take on a distinctive shape from a new hammer head. The rivet will be cold driven for speed, ease of fabrication, economy, and development of high clamping force. It will be stronger in shear, bearing and tensile strength. It will reduce peak stress concentrations around holes.

KEY WORDS: clamping; deformation; fabrication; joint, friction; rivet; riveting, cold; riveting, hot; stresses

(226)

Chesson, E., Jr., and Munse, W. H.
STATUS REPORT OF PRELIMINARY STUDIES COMPARING A354 AND A325 HIGH STRENGTH BOLTS, Dept. of Civil Engineering, University of Illinois, August 1962.

This report summarizes the results of direct-tension and torqued-tension calibration tests of A325 and A354 BC and BD bolts. Also included are the results of 12 relaxation tests of A354BD bolts in A7 steel plates. Interaction curves for combined tension and shear are also presented. The reports compares the A325 and A354 bolts. Both bolts exhibit torque strength of about 85% of tensile strength. When hardened washers are provided at the turning surface, the torque relationship T = 0.2PD holds for both bolts. The A354 bolt requires more turns to reach proof load than the A325 bolt. Relaxation studies and combined tension and shear behavior are similar. In general, thread reduction in the grip increases maximum bolt load but decreases turns to failure.

KEY WORDS: bolt; relaxations; shear test; torque; washers

(227)

Fisher, J. W., and Beedle, L. S.
CRITERIA FOR DESIGNING BOLTED JOINTS (BEARING TYPE), Fritz Engineering Laboratory, Report No. 288.7, Lehigh University, Bethlehem, Pa., February 1963.

This report reviews the current criteria for proportioning bearing-type bolted joints. The concepts and practices that led to the "balanced design" concepts are discussed. Results of tests of bolted butt joints of A7 or A440 steel connected with A325 bolts are analyzed and compared with theoretical results. The examination of the current design concept showed that: (1) the concept of balanced design leads to inconsistent allowable bolt stresses for different plate materials, (2) the A325 bolt behaves similarly under shear in a compact joint regardless of the type of connected material, and (3) the balanced design concept has no meaning in long joints because the bolts unbutton before the plate material can attain its full strength. A different design basis is suggested and possible design guides are outlined.

KEY WORDS: bolts; design; joints; steel; structural engineering

(228)

Christopher, R. J., and Fisher, J. W.
CALIBRATION OF A354 BOLTS, Fritz Engineering Laboratory Report No. 288.9, Lehigh University, Bethlehem, Pa., February 1963.

Presented are the results of 54 direct tension and 110 torqued tension calibration tests of individual ASTM A354BC and A354BD quenched and tempered alloy steel bolts. The bolts were 7/8 in. and 1 in. with lengths under head which varied from 5-1/4 to 9-1/2 in. The major variables studied were diameter, grip, thread in grip, and thread lubrication. The results indicate that: (1) the ultimate strength in direct tension is 6 tp 27% greater than in torqued tension, (2) a lesser amount of exposed thread under the nut results in an increase in ultimate strength and a decrease in rotation capacity, (3) thread lubrication has no appreciable effect on bolt performance and, (4) proof load can not be reached by 1/2 turn-of-nut for grips between 7.6 and 8 in.

KEY WORDS: bolts; joints; steel; structural engineering; testing

(229)

Chang, W. N., and Vasarhelyi, D. D.
THE COEFFICIENT OF FRICTION IN BOLTED JOINTS AND MISALIGNMENT IN BOLTED JOINTS, Dept. of Civil Engineering, University of Washington, Eleventh Progress Report to RCRBSJ, February 1963.

Part I, which is in general concerned with friction, discusses a proposed program of 18 tests on 4 bolt double-lap butt splices. Eight of the specimens are to be fabricated from A36 steel, 2 from A440 steel, 2 from T1 steel, and 2 from A36 and A440, 2 from A440 and T 1, and 2 from A36 and T1. A preliminary study of means of measuring the roughness of mill scale surfaces is described. Among the methods described are mechanical measurements, photography, and micro-stereo-photogrametry. A standard bolted specimens proposed for tests to determine the coefficient of friction consists of a 1 in. main plate and two 1/2 in. lap plates connected by 4 1" A325 bolts tightened to a preload of 50 kips per bolt. In Part II of this report the results of 5 tests of double-lap tension splices are reported. The test specimens were A7 steel plate connected by 4 rows of 3 3/4 in. A325 bolts. Four of the joints had 1 or more holes misaligned. In joints with misaligned fasteners a marked geometric adjustment takes place between the load causing first slip and the load at which the joint yields. The presence of initially misaligned fasteners did not significantly reduce the ultimate load-carrying capacity or the or the joint efficiency. The impairment of the self-adjusting capacity of the misaligned joint due to cleavage does not take place until after slip occurs.

KEY WORDS: alignment; bolts; friction; slippage

(230)

Douty, R. T., and McGuire, W.
RESEARCH ON BOLTED MOMENT CONNECTIONS-A PROGRESS REPORT, Proceedings, AISC, April 1963, pp. 48-55.

Presented is a summary of tests conducted at Cornell University on high-strength bolted moment connections. The tests, which were made on T-stub, flange splice, and end plate moment connections, were designed to provide more information about the use of these connections in plastically-designed structures. The conventional beam splices had 3/4 in. or 7/8 in. A325 bolts designed for nominal shear stresses on the body diameter varying from 15 to 30 ksi. All splices were able to develop the fully plastic moment of the gross section. A theoretical solution was developed for the behavior of flange and bolts in the T-stub connections. The theory was compared first with straight tension tests of T-stub bolted to rigid and flexible bases. Finally three tests of assembled beam-to-column moment connections were made. Specimens were fabricated with web clips omitted off one beam of each specimen. The authors conclude that the web clips are desirable. Six end plate moment connections were tested, five in pure bending and one in an assembled beam-to-column connection. The variation in bolt tension and the development of prying forces as well as the deformation and resistance of the plate and bolt combinations were studied. It is concluded that the critical design condition for the end plate is horizontal bending on a line through the lowest bolt row caused by the tension in the beam flange, and that only as being fully effective if the end plates are flexible. Both the stiffners and rotation characteristics were excellent for the end plate connections.

KEY WORDS: analyzing; bolts; joints; steel; structural engineering; testing

(231)

Chang, W. N., and Vasarhelyi, D. D.
MISALIGNMENT IN BOLTED JOINTS, Twelth Progress Report to RCRBSJ, Dept. of Civil Engineering, University of Washington, Seattle, Washington, July 1963.

The effect of misalignment on slip, elongation, efficiency, and adjustment are outlined. Six tests were conducted on bolted butt splices connected by 12 high-strength bolts (3/4 in.). The holes were misaligned in 5 specimens by various patterns. The test results are analyzed and compared with similar tests reported in Abstract 209. The results indicate that in misaligned joints the geometric and plastic self-adjustment occurs at loads between the load causing first slip and the load at which the member yields. Slip was found to occur more gradually in the misaligned joints and no effect was noted on the overall elongation of the joint. The authors conclude that a single row of misaligned fasteners show a slight reduction in efficiency whereas a misaligned pattern on or about a diagonal had little influence on efficiency.

KEY WORDS: alignment; bolts; efficiency; joints; slippage; strength; testing

(232)

Chesson, E., Jr., and Munse, W. H.
STUDIES OF THE BEHAVIOR OF HIGH-STRENGTH BOLTS AND BOLTED JOINTS, Dept. of Civil Engineering, University of Illinois, Urbana, December 1963.

A325 and A354BD bolts were used in tests which demonstrated that washers have no significant effect on the clamping force of high-strength bolts tightened with a turn-of-nut method. Additional turning is required in a turn-of-nut method when the surfaces at the head and nut are on 5% slopes. Thirty-eight fatigue tests were made with 4-bolt double-lap shear-type joints. Some specimens had the outside plates critical, while others had the inside plates critical. The tests showed that washers generally have no effect on the fatigue lives of properly-bolted A325 joints.

KEY WORDS: bolts; fatigue; joints; steel; structural engineering; testing

(233)

Fisher, J. W., Ramseier, P. O., and Beedle, L. S.
STATIC STRENGTH OF A440 STEEL JOINTS FASTENED WITH A325 BOLTS, Publications, IABSE, Vol. 23, 1963, pp. 320-345. (First distributed as Fritz Engineering Laboratory Report No. 288.4, Lehigh University, Bethlehem, Pa., 1963).

Tests of A440 steel structural joints connected with A325 high-strength bolts installed by the turn-of-nut method were conducted to determine their slip resistance and ultimate strength. The purpose of the test program was to establish an approximate "balanced" relationship between the shear strength and the plate tensile strength and to determine the influence of joint length on the ultimate strength of higher-strength steel connections. Eleven of the joints tested had 2 lines of 7/8 in. A325 bolts, with 4 to 16 bolts in line. Other joints had 4 and 6 lines of bolts. The ultimate strength of the joints correlated well with the theoretically-predicted values based on the non-linear behavior of the component parts. A decrease in the average shear strength accompanied increasing joint length. This decrease was not nearly as great as it was in A7 steel joints. The tests yielded a mean coefficient of 0.32 for tight mill scale faying surfaces.

KEY WORDS: bolts; joints; slippage; steel; strength; structural engineering; tensile strength; testing

(234)

Fisher, J. W.
THE ANALYSIS OF BOLTED PLATE SPLICES, Ph. D. Dissertation, Lehigh University, Bethlehem, Pa., February 1964. (Distributed as Fritz Engineering Laboratory Report No. 288.10, Lehigh University, Bethlehem, Pa., February 1964).

A theoretical solution is developed for the unequal distribution of load among the mechanical fasteners of bolted double-lap tension splices which act in a non-linear manner. To accomplish this solution, mathematical models were developed which establish the relationship between deformation and load throughout the elastic and inelastic regions for the component parts of the connections. The solution was used to make a number of hypothetical studies in order to ascertain the relative importance of a number of parameters on the ultimate strength of the connections. Among the variables studied were joint length, pitch, variation in fastener diameter, and variation in the relative proportions of the bolt shear area and the net tensile area. The theoretical solution was compared with test results of 8 full-size connections using 7/8 in. A325 bolts and A7 steel plate and 7 full-size connections using 7/8 in. A325 bolts and A440 steel plate. The maximum deviation between the theoretical solution and the test results was 4%.

KEY WORDS: bolts; joints; steel; structural engineering; tensile strength

(235)

Chiang, K. C., and Vasarhelyi, D. D.
THE COEFFICIENT OF FRICTION IN BOLTED JOINTS MADE WITH VARIOUS STEELS AND WITH MULTIPLE CONTACT SURFACES, Dept. of Civil Engineering, University of Washington, Seattle, February 1964.

Twenty-nine tests of butt splice joints of A7, A36, A440, and T1 steels clamped by four 1-inch high-strength A325 steel bolts were made to develop an easily determinable parameter to estimate frictional characteristics of surfaces and for the possible standardization of friction coefficient tests for joints. For joints made of one steel, the nominal coefficient of friction is a result of the conditions under which the mill scale formed. The coefficient of friction for joints of two kinds of steel does not seem to be predictable from the indivuidual coefficients of friction of the components.

KEY WORDS: area, faying; bolt; friction; joints

(236)

Troup, E. W. J., and Chesson, E., Jr.
CALIBRATION TESTS OF A490 HIGH-STRENGTH BOLTS, Dept. of Civil Engineering, University of Illinois, SRS No. 280, March 1964.

Over fifty calibration tests on 7/8 in. ASTM A490 high-strength bolts were conducted. Data on bolt tension, elongation, turns of nut, and general behavior were taken and analyzed. Comparisons made of bolt behavior when torqued in a commercial load cell and in a solid steel block show that a significant difference exists between these two conditions. The general characteristics of the A490 high-strength bolt appear to be similar to those of the familiar A325 bolts, but the physical properties of the new bolt will provide greater fastener strength and joint clamping.

KEY WORDS: bolt; elongation; physical properties; tension

(237)

Chesson, E., Jr., Faustino, N. L., and Munse, W. H.
STATIC STRENGTH OF HIGH-STRENGTH BOLTS UNDER COMBINED TENSION AND SHEAR, Dept. of Civil Engineering, University of Illinois, Urbana, March 1964.

Presented is a study of the strength and behavior of single high-strength bolts under static loadings of tension and shear. A total of 115 A325 and A354 Grade BD high-strength bolts were tested. The results were analyzed with consideration being given to such factors as location of the shear plane of loading, proportion of tension and shear loads, length of grip, bolt type, and type of material bolted. The maximum strength of a bolt may be realized at a combination of tension and shear which is only predominantly tension and rather than pure tension.

KEY WORDS: bolt; shear test; tension; tensile strength

(238)

Sterling, G., and Fisher, J. W.
TESTS OF A490 BOLT (PRELIMINARY REPORT), Fritz Engineering Laboratory Report No. 288.15, Lehigh University, Bethlehem, Pa., March 1964.

Tests were conducted on 2 lots of A490 bolts at Lehigh University and the University of Illinois to determine if testing procedures constitute a major variable. The results of the work at Lehigh are given in this report. The results of 20 direct-tension and 30 torqued-tension tests made on 7/8 in. x 5-1/2 in. and 7/8 in. x 9-1/2 in. A490 alloy steel bolts are reported. The torqued-tension tests were conducted in a hydraulic calibrating device and in a solid block of A440 steel. The tests showed that the direct tensile strength was 10 to 20% greater than the torqued tension strength. The average load at 1/2 turn from snug was less than proof load for the longer bolts. The shorter bolts reached proof load at 1/2 turn when tightened in the solid steel block, but only those specimens with 1/8 in. of thread in the grip reached proof load at 1/2 turn when torqued in the hydraulic load device. This study shows that additional rotation beyond 1/2 turn is necessary for the longer A490 bolts if the proof load is to be reached.

KEY WORDS: bolts; joints; steel; structural engineering; testing

(239)

Chesson, E., Jr.
EQUIPMENT FOR RESEARCH ON RIVETED JOINTS, Bulletin No. 22, RILEM, Paris, France, March 1964, pp. 66-67.

The equipment used at the University of Illinois for measuring strain, stress, and deformation in studies of riveted and bolted structural joints are described. Besides that which is commercially available, such as electrical resistance strain gages, specially designed equipment is used. It includes hollow cylinders with strain gages to record axial load produced by bolt tightening, "C-frame" extensometers equipped with direct-reading dial gages, and a counter-weighted device which also measures bolt elongation. A device for measuring the slip of truss bridge joints to ± 0.0005 in. was made for field testing of a 310 ft. railway span.

KEY WORDS: bolts; instrumentation; joints; rivets; testing

(240)

Chesson, E., Jr.
HIGH STRENGTH FASTENERS VERSUS RIVETS, Presented at the Building Research Institute Conference on "Significance of Mechanical Fasteners in Building Construction", BRI Conferences, Washington, D. C., April 1964.

A brief history of the use of rivets and bolts as structural fasteners is presented. The changes in specifications by ASTM and RCRBSJ are briefly discussed. The physical properties of various types of rivets and bolts are compared along with the advantages and disadvantages of both from the standpoints of cost of materials, equipment, and labor. The trends toward more and more use of high-strength bolts are explained.

KEY WORDS: bolts; costs; fasteners; force, clamping; properties; rivets

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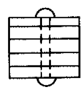
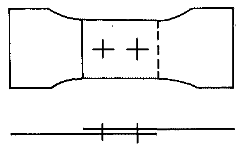
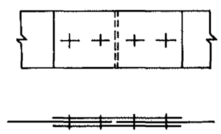
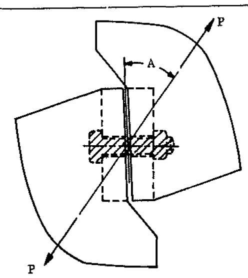
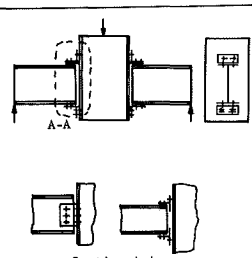
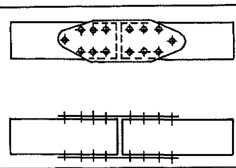
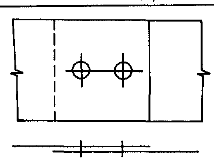
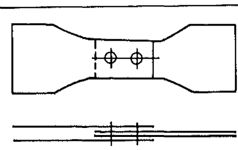
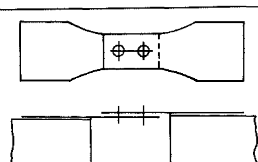
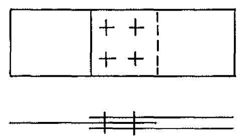
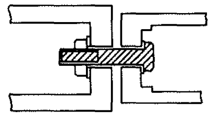
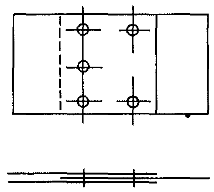
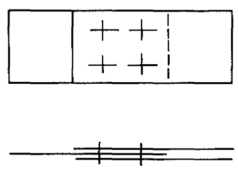
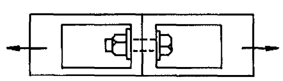
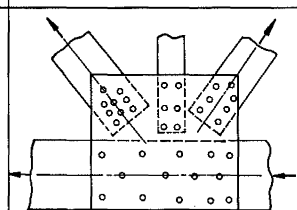
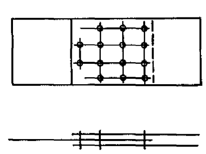
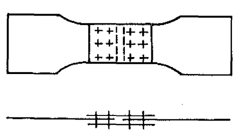
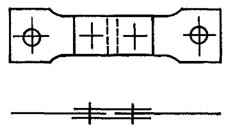
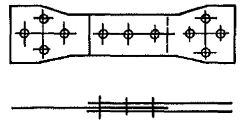
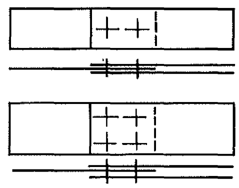
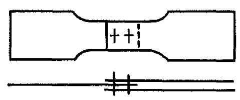
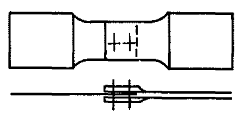
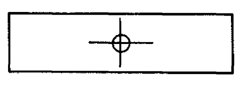
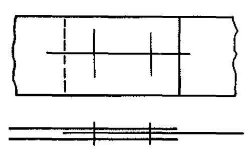
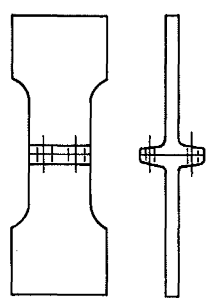
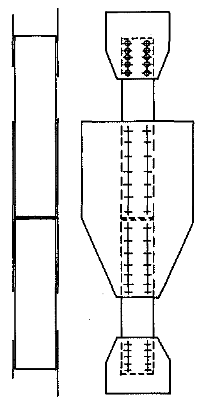
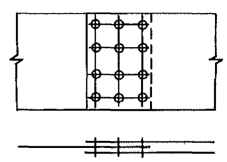
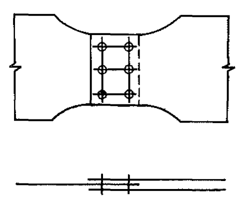
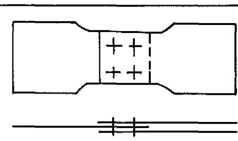
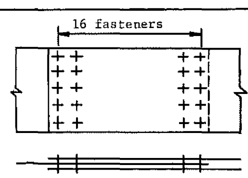
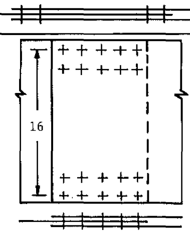
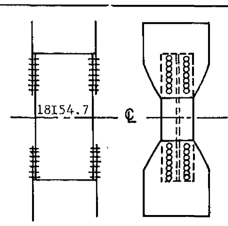
7. TABLES

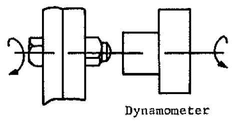
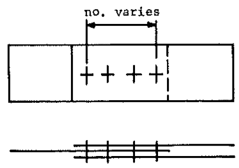
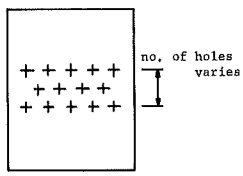
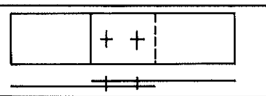
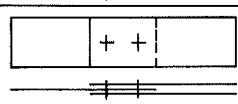
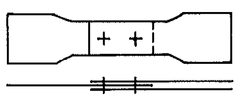
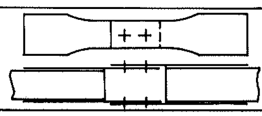
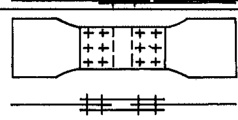
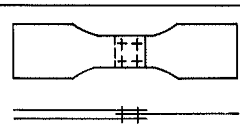
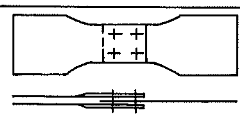
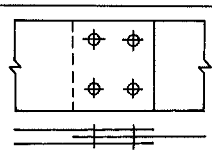
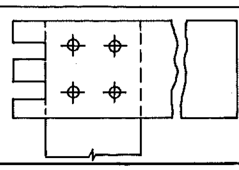
The Ref. No. shown in the first column of these tables is the same as that used in "Abstracts" and "List of References".

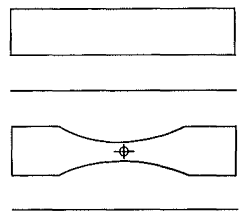
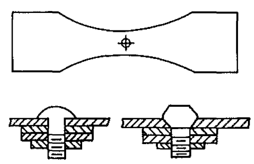
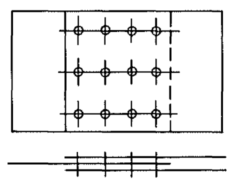
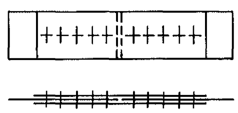
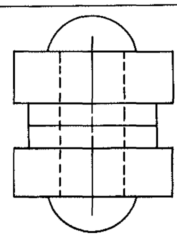
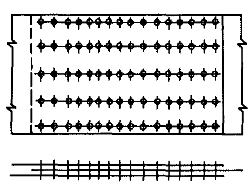
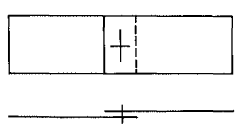
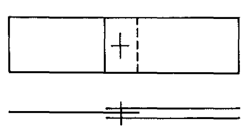
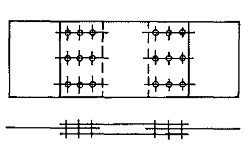
REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
3	A141 steel rivets	Flange-web connection		Position in plate girder	28 tests-7/8" rivet to determine clamping force	
8	AN6-6, AN6-7, & AN6-11 steel bolts	Lap splice		Joint size Plate thickness Bolt pattern Bolt fit Stress range	Static Tension Tests 60 tests 3/8" A6 bolt Fatigue Tests 788 tests 3/8" A6 bolt 11 tests 1/4" A6 bolt 7 tests 15/32" A6 bolt	
13	S.A.E. 2330 steel bolts	Butt splice		Joint length Plate thickness Number of bolts	Static Tension Tests 6 tests 1/4" bolt	1. Development of load-deformation relationship for bolts in shear (elastic) 2. Analysis of load partition in bolted butt splices
14	A307 bolts	Test jig		(A) Angle of applied load	Static Tension Tests 64 tests of 0.369" bolt	1. Computation of a. Simple sum of unit shear and unit tensile stress b. Vector sum of unit shear and unit tensile stress c. The principle stress d. The maximum shearing stress
15	A141 steel rivets	Beam-to-column	 Section A-A	Beam size Beam length Column size Angle size Rivet diameter Connection to column flange or web	Static Tests 34 tests top and seat angles 2 tests top and seat angles to one side of column web 2 tests top, seat, and web angle 4 tests standard web angle connection 1 test web clip and seat angle 1 test tees on both beam flanges 1 test tees on both beam flanges and web angles	1. Computation of percentage of rigidity
19	24S-T rivets	Gusset plate (lap splice)		Gusset material Column material Gusset size Gusset edge finish Fastening method Stress range	Fatigue Tests 21 tests 24S-T rivet 24S-T gusset 13 tests 24S-T rivet Alloy steel gusset 15 tests spot welds 24S-T gusset	1. Computation of initial maximum shear stress
31	A325 steel bolts	Lap splice and lap with bracing		Stress range	Fatigue Tests 4 tests 7/8" bolt	
		Butt splice			Fatigue Test 1 test 7/8" bolt	
		Double lap splice		Bracing length Stress range	Static Tension Tests 22 tests 7/8" bolt Fatigue Tests 30 tests 7/8" bolt	

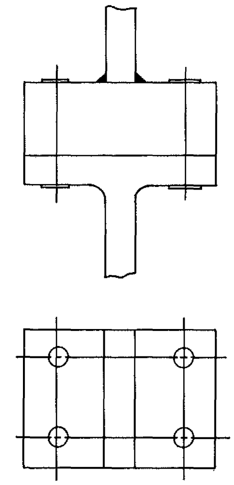
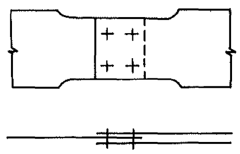
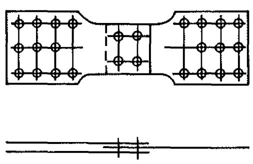
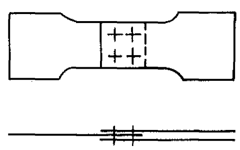
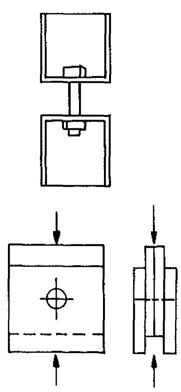
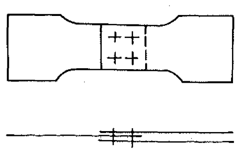
REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
32	A325 steel bolts	Butt splice		Stress range	<u>Fatigue Tests</u> 2 tests 1" bolt	
41	A325 steel bolts	Test jig		Bolt size Grip length Area of bolt shank Surface treatment	<u>Combined Direct and Torqued Tension Tests</u> 8 tests 3/4" bolts 8 tests 7/8" bolts 22 tests 1" bolts	1. Computation of torque coefficient.
42	A141 steel rivets	Butt splice		Joint size Plate thickness Rivet diameter	<u>Static Tension Tests</u> 16 tests 3/4" rivet 16 tests 1" rivet	1. Computation of joint efficiencies.
43	SAE 4140 Steel bolts	Butt splice		Joint size Bolt pattern Bolt tension Surface preparation	<u>Static Tension Tests</u> 18 tests 63/64" bolt	1. Computation of coefficient of friction
52	BSF 511 Steel bolts	Test jig		Bolt pretension Load range Thickness of washer	<u>Fatigue Tests</u> 17 tests 3/4" bolt	Computation of ratio of $\frac{\text{Change in bolt load}}{\text{Change in external load}}$
54	Aluminum Alloy Bolts	Gusset Plate for Warren Truss		Direction of applied load	<u>Static Tests</u> 2 tests 1/4" bolt 61-ST plate	1. Computation of maximum tensile, compressive and shearing stress, and their directions.
55	A141 steel rivets	Butt splice		Joint size Plate thickness Rivet pattern Rivet size Test temperature	<u>Static Tension Test</u> 12 tests 7/8" rivet 24 tests 3/4" rivet	1. Computation of joint efficiencies
58	A141 steel rivets A325 steel bolts	Butt splice		Plate thickness Type of fastener Length of grip Tension-shear-bearing ratio Diameter of holes Fabricator	<u>Fatigue Tests</u> 46 tests 3/4" A325 bolt 98 tests 3/4" A141 rivet <u>Static Tension Test</u> 3 tests 3/4" A325 bolt 21 tests 3/4" A141 rivet	1. Computation of joint efficiencies.

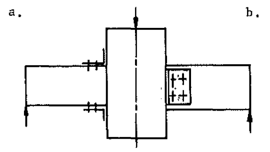
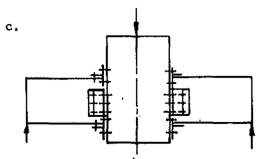
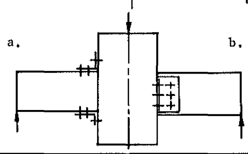
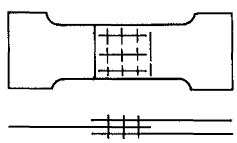
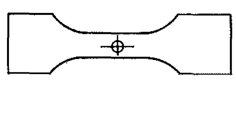
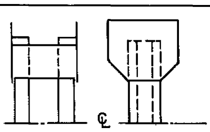
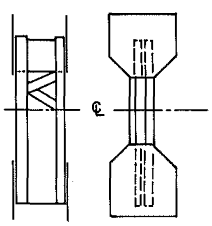
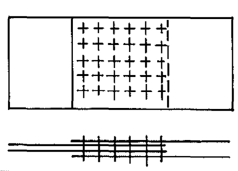
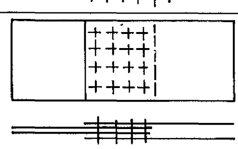
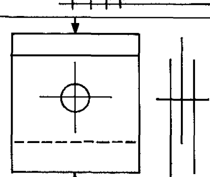
REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
64	NR6 steel rivets or Mild steel rivets	Butt splice		Joint size Plate thickness Rivet diameter Rivet material Rivet pattern Loading condition	Static Tension Test NR6 rivets 8 tests 3/4" rivet 8 tests 1/2" rivet 1 test 1/4" rivet Mild steel rivet 2 tests 3/4" rivet 6 tests 1/2" rivet	1. Partitions of load in joint 2. Overall elongation of joint 3. Computation of loss of efficiencies 4. Computations of ultimate strength
		Butt splice			Eccentric Load Tests NR6 rivets 8 tests 1/2" rivet Mild steel rivets 9 tests 1/2" rivet	1. Computation of failure loads
68	A195 steel rivets A141 steel rivets	Butt splice		Joint size Plate thickness Edge condition Rivet diameter Grip length	Static Tension Tests 12 tests 3/4" alloy rivet 6 tests 7/8" alloy rivet 6 tests 1" alloy rivet	
		Butt splice		Joint size Plate thickness Rivet materials Grip length Tension-shear-bearing ratio	Static Tension Tests 2 tests 3/4" carbon rivets 4 tests 3/4" alloy rivet Fatigue Tests 11 tests 3/4" carbon rivets 21 tests 3/4" alloy rivet	1. Computation of joint efficiencies
		Butt splice		Rivet materials	Static Tension Tests 1 test 3/4" carbon rivet 1 test 3/4" alloy rivet Fatigue Tests 5 tests 3/4" carbon rivet 5 tests 3/4" alloy rivet	
69		Plate with hole		Kind of steel Roughness of plate surfaces	Static Tension Tests 7 tests A242 steel 1 test rimmed steel 3 tests A7 steel 4 tests A94 steel Fatigue Tests Total 109 tests.	
71	A141 steel rivets A307 bolts A325 bolts	Butt splice		Plate width Plate thickness Bolt diameter Bolt tension T:S:B ratio	Static Tension Tests 2 tests 3/4" rivet 2 tests 3/4" A307 bolt 4 tests 7/8" A307 bolt 14 tests 3/4" A325 bolt	1. Computation of joint efficiencies.
74	A325 steel bolt A141 steel rivets	T section butt		Initial bolt tension Applied load Bolt spacing The use of non-parallel surfaces between the heads of bolts and the joined members	Static Tension Tests 5 tests 3/4" bolt 1 test 3/4" rivet Fatigue Tests 18 tests 3/4" bolt 3 tests 3/4" rivet	1. Computation of joint efficiencies.

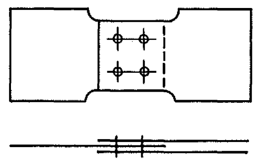
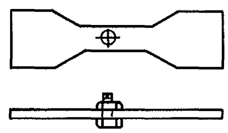
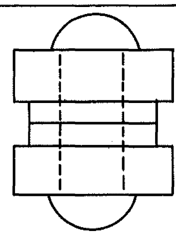
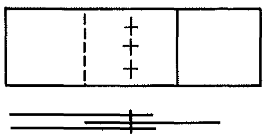
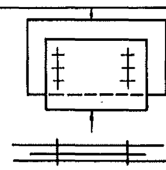
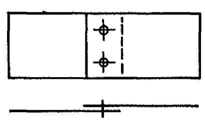
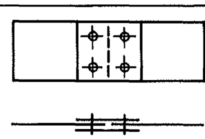
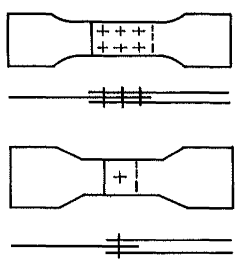
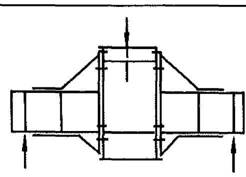
REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
75	A141 steel rivets A325 steel bolts	Two W beams with gusset plates		Fastener type	Static Tension Test 1 test 7/8" bolt 1 test 7/8" bolt and 7/8" rivet	1. Computation of principal stresses in gusset plate
80	A141 steel rivets	Butt splice		Joint size Rivet pattern	Fatigue Tests 45 tests 3/4" rivet Static Tension Test 20 tests 3/4" rivet	1. Computation of apparent coefficient of friction 2. Computation of joint efficiencies
				Joint size Rivet pattern Plate thickness Rivet diameter	Fatigue Tests 42 tests 3/4" rivet 12 tests 7/8" rivet 36 tests 1" rivet Static Tension Test 16 tests 3/4" rivet 4 tests 7/8" rivet 12 tests 1" rivet	
81	SAE 4140 steel bolts	Butt splice		Joint size Plate thickness	3 static tension tests	1. Computation of coefficient of friction 2. Computation of load partition in the joint based on measured strains
	A325 steel bolts				2 static tension tests	
					2 static tension tests	
82	A325 steel bolts A141 steel rivets	I-section with gusset plate		Washer type Type fastener	Static Tension Test 2 tests 7/8" bolt 1 test 7/8" rivet	1. Computation of load resisted by the webs 2. Computation of joint efficiencies.

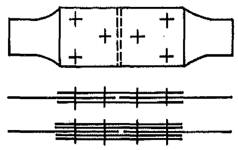
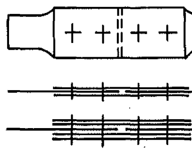
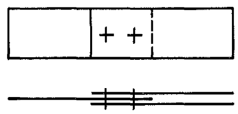
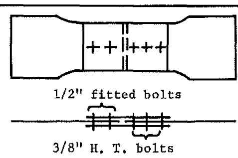
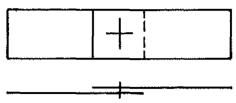
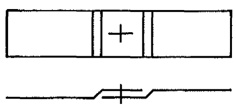
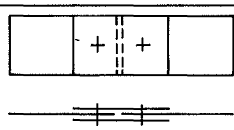
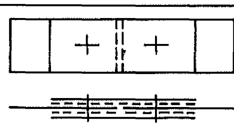
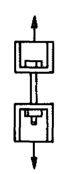
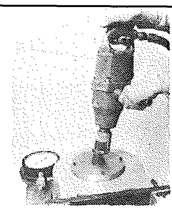
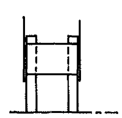
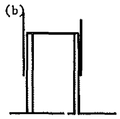
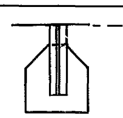
REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
83	A325 steel bolts	Test jig	 Dynamometer	Bolt diameter Bolt length Air-pressure of pneumatic wrenches Time interval Nut rotation	1200 tests of single bolts	
87	SAE 1020 steel bolt Brass 60/40 bolt 24ST bolt Lucite bolt	Butt splice		Bolt materials Number of bolt	Static Tension Tests 4 tests SAE 1020 bolt 4 tests brass 60/40 bolt 4 tests 24ST bolt 4 tests lucite bolt	1. Computation of joint modulus. 2. Computation of load carrying capacity and load partition in the elastic region.
90		Plate with holes		Plate materials Number of holes Pattern of holes	Static Tension Tests 29 tests hot rolled steel no holes 11 tests hot rolled steel with holes 6 tests 61S-T6 aluminum no holes	1. Computation of stress ratio 2. Limit Analysis
92	A325 steel bolts A141 steel rivets	Lap splice		Plate thickness Bolt diameter Number of bolts Contact surface preparation Bolt Tension Tension-shear ratio	Static Tension Tests 32 tests 3/4" bolt 12 tests 3/4" bolt	1. Computation of joint efficiencies
		Butt splice			Static Tension Tests 12 tests 3/4" bolt	
		Butt splice		Stress range Bolt diameter Bolt tension Type fastener	Fatigue Tests 35 tests 1" bolt 5 tests 7/8" bolt 3 tests 5/8" bolt 3 tests 3/4" bolt 3 tests 7/8" rivet	1. Computation of the fatigue strength
		Double lap splice		Loading range Bracing length	Fatigue Tests 3 tests 7/8" bolt	
95	A141 steel rivets A195 steel rivets A325 steel bolts	Butt splice		Type of fastener Tension shear bearing ratio Length of grip Fastener materials Loading range	Fatigue Tests 24 tests 3/4" A325 bolt 56 tests 3/4" A141 rivet	1. Computation of joint efficiencies
		Butt splice		Plate thickness Tension shear bearing ratio Length of grip Surface preparation Fastener Materials Hole preparation	Fatigue Tests 5 tests 3/4" A141 rivet 7 tests 3/4" A195 rivet	
		Butt splice		Fastener materials	Fatigue Tests 2 tests 3/4" A141 rivet 2 tests 3/4" A195 rivet	
96	4140 steel bolts A325 steel bolts	Butt splice		Joint size Plate thickness Surface condition Bolt materials Tension-shear ratio	Static Tension Tests 48 tests 1" 4140 steel bolt 13 tests 1" A325 steel bolt	1. Computation of coefficient of friction
				Moment-shear ratio	Static Torsion Test 6 tests 1" 4140 steel bolt	1. Computation of shear stresses by Gullander method.

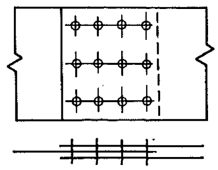
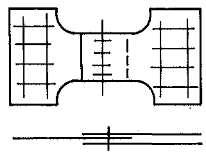
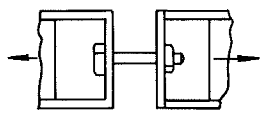
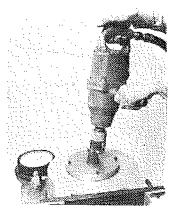
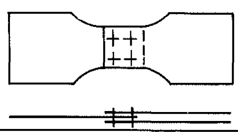
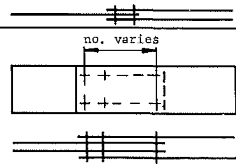
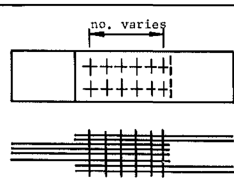
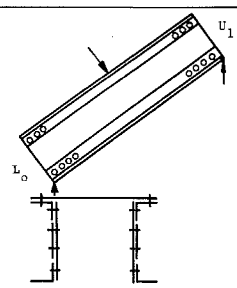
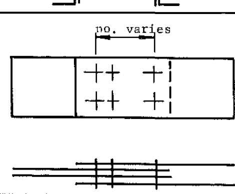
REF. NO.	CONNECTION				NOTES	
		TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
100	ALPPH Huck bolts ACT509H Huck bolts	Plain plate or plate with holes		Type of hole	<u>Fatigue Tests</u> 31 tests 7075-T Alclad sheet	1. Computation of the fatigue strength reduction factor.
		Plate with bolt installed		Type of hole Interference Depth of countersink	<u>Fatigue Tests</u> 67 tests 1/4" Brazier-head Huck bolts 7075-T plate	
101	A325 steel bolts	Butt splice		Plate thickness Hole preparation Plate surface condition Tested temperature Tension-shear ratio	<u>Static Tension Test</u> 12 tests 3/4" bolts at room temperature 6 tests 3/4" bolts at -24°F.	1. Computation of joint efficiencies 2. Strain-Energy absorption of the joint.
106	A325 steel bolts	Butt splice			1 Static Tension Test	1. Computation of local coefficient of friction
108	A141 steel rivets	Test jig		Grip length Rivet diameter Type of rivet Type of rivet steel Driving method Shear-tension ratio	<u>Static Tests</u> 3/4" rivets 82 tests 7/8" rivets 85 tests 1" rivets 82 tests	Development of empirical interaction curve for combined tension and shear.
110	A325 steel bolts	Butt splice		Joint size Plate thickness Bolt pattern	<u>Static Tests</u> 4 tests 1" bolt	1. Computation of load partition from strain reading. 2. Computation of joint efficiencies.
112	ALPPH-T8 Huck bolts	Lap splice		Clamping force Collar material Interference	<u>Fatigue Tests</u> 6 tests 1/4" Huck bolts 7075-T plate	
		Butt splice		Clamping force Collar material Interference Surface preparation	<u>Fatigue Tests</u> 8 tests 1/4" Huck bolts 7075-T plate 8 tests 1/4" Huck bolts 2024-T plate 14 tests 1/4" Huck bolts 7075-T plate 3 surface conditions	
113	A325 steel bolts A354 steel bolts	Butt splice			1 Static Tension Test 7/8" A325 and A354 bolts	

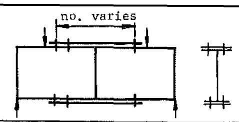
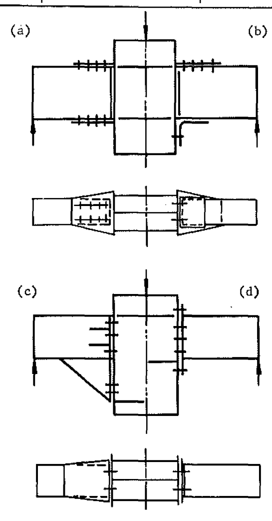
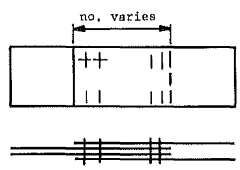
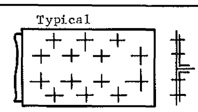
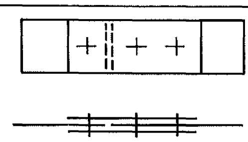
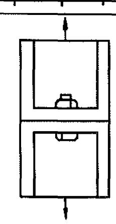
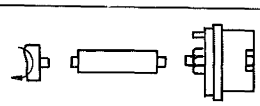
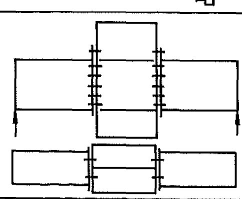
REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
119	A325 steel bolts	T-section		Bolt size Number of bolts	<u>Static Tension Test</u> 5 tests 7/8" bolt 1 test 5/8" bolt	1. Development of interaction curve for strength in tension and shear 2. Computation of the ultimate strength of bolted tee connection.
120	A325 bolts	Butt splice		Bolt tension	<u>Static Tension Tests</u> 26 tests 1" bolt	1. Computation of coefficient of friction.
121	Hook-Knurl A325 bolt High tensile bolts A325	Butt splices		Grip length Bolt type	<u>Static Tests</u> 3 tests high strength bolt 3 tests Hook-knurl bolt <u>Fatigue Tests</u> 4 tests high strength bolt 8 tests Hook-knurl bolt	
122	A325 steel bolts	Butt splice		Internal tension Frequency of vibration	<u>Static Tension Tests</u> 29 tests without vibration 33 tests with vibration	1. Computation of slip coefficient
123	A325 steel bolts	Test jig		Clamping force	<u>Direct Tension Tests</u> 1 test 7/8" bolt 1 test 1" bolt <u>Shear Tests</u> 2 tests 7/8" bolt 2 tests 1" bolt	
126	A325 steel bolts	Butt splice		Surface preparation	<u>Static Tension Tests</u> 35 tests 1" bolt	1. Computation of coefficient of friction

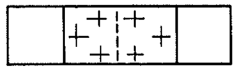
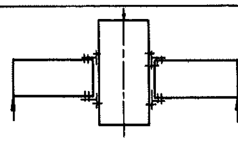
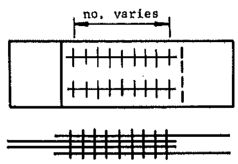
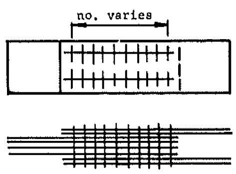
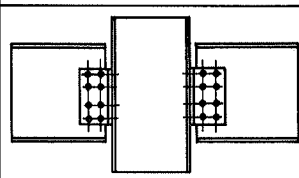
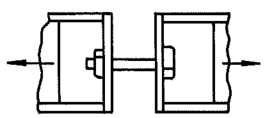
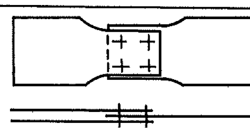
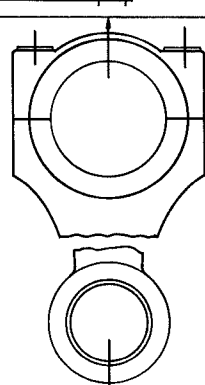
REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
128	A141 steel rivets A325 steel bolts	Column Base a. Flange angle b. Web angle	 	Fastener type Type of load Type of loading stub	Static Tests One test with slowly applied load and the second test with rapidly applied load a. 3 tests 3/4" rivet 2 tests 3/4" bolt b. 2 tests 3/4" rivet 2 tests 3/4" bolt	1. Development of moment-rotation relationships
		Column-to-beam a. Flange angle b. Web angle c. Tee	  	Fastener type Type of load	Static Tests a. 2 tests 3/4" rivet 2 tests 3/4" bolt b. 2 tests 3/4" rivet 2 tests 3/4" bolt c. 2 tests 3/4" rivet 2 tests 3/4" bolt	
130	A325 bolts	Butt splice		Loading condition	Constant Cycle Fatigue Tests 19 tests 3/8" bolt Variable Cycle Fatigue Tests 16 tests 3/8" bolt Static Tension Tests 2 tests 3/8" bolt	1. Development of S-N relationship 2. Computation of the distribution coefficient $\beta = f(\frac{N_A}{N_A+N_a})$ 3. Computation of joint efficiencies
		Plain plate		Loading condition	Constant Cycle Fatigue Tests 38 tests Variable Cycle Fatigue Tests 5 tests	
132	A141 steel rivets A325 steel bolts	Box section with batten plates		Specimen configuration	Static Tension Tests 2 tests 3/4" rivet 1 test 3/4" bolt	1. Distribution of load to pull plates 2. Computation of joint efficiencies 3. Computation of joint deformation in the elastic range
		a. Laced angles b. Built-up I section		Size of joint Rivet pattern Rivet diameter Hole preparation	Static Tension Tests a. 8 tests 7/8" rivet 4 tests 3/4" rivet 3 tests 3/4" bolt 1 test weld b. 2 tests 7/8" rivet	
133	A325 steel bolts A141 steel rivets	Butt splice		Joint size Bolt or rivet pattern Tension-shear ratio Fastener type	Static Tension Tests 6 tests 7/8" bolt 1 test 7/8" rivet	1. Computation of joint efficiencies 2. Computation of coefficient of friction 3. Computation of effective area in elongation
136	A325 steel bolts	Butt splice		Joint size Tension-shear ratio Bolt pattern	Static Tension Tests 1 test 1" bolt 1 test 1-1/8" bolt	1. Computation of coefficient of friction 2. Computation of joint efficiency
137	A325 steel bolts	Test jig		Surface preparation Bolt diameter Initial tension	Static Tests 7/8" bolts 1" bolts 1-1/8" bolts	1. Computation of the ratio of effective shear stress to tensile stress on stress area

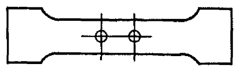
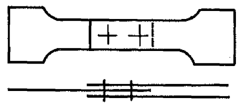
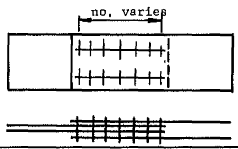
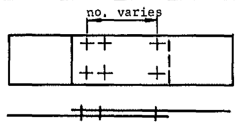
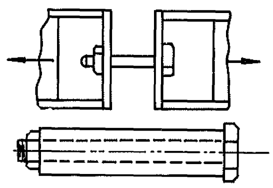
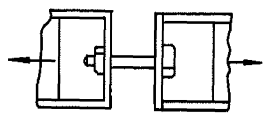
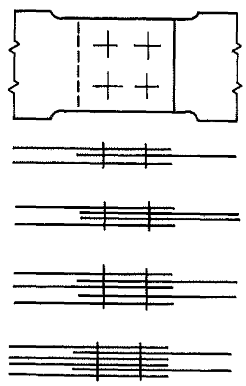
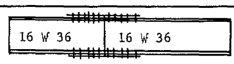
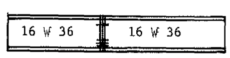
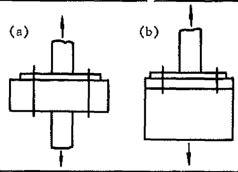
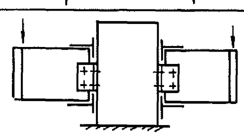
REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
138	A141 steel rivets	Butt splice		Joint size Plate thickness Bearing ratio Load range	Fatigue Tests 7/8" rivets and A7 steel plates 26 tests zero to tension 8 tests full reversal Static Tests 4 tests	1. The fatigue strength of various clamping forces. 2. Joint efficiency.
140	A325 steel bolts	Plate		Type of nut Stress range	Fatigue Tests 4 tests 3/4" bolt flanged nut 3 tests 3/4" bolt heavy nut 2 tests open hole	
141	A325 bolts	Test jig (See Ref. 108)		Length of bolt Tension-shear ratio Loading condition	11 tests of 4 in. bolts 5 tests of 2-3/4 in. bolts	1. Development of empirical interactio curve for combined tension and shea
144	A141 steel rivets	Double lap butt splice		Joint size Plate thickness Rivet diameter Rivet pattern	Static Tension Tests 33 tests 3/4" rivet 24 tests 7/8" rivet 64 tests 1" rivet	1. Computations of joint efficiencies
		Double lap butt splice		Joint size Plate thickness Rivet diameter	Static Compression Tests 18 tests	
146	A325 steel bolts	Lap splice		Bolt type Nut type Washer or no washer	Static Tension Tests 6 tests 3/4" rib bolt 3 tests 3/4" hex head bolt	
		Butt splice			Static Tension Tests 6 tests 3/4" rib bolt 3 tests 3/4" hex head bolt	
150	A325 steel bolts	Butt splice		Joint size Plate thickness Bolt pattern Tightening torque Surface preparation	Static Tension Tests 230 tests 1" bolt Fatigue Tests 15 tests 1" bolt	
151	B.S. No. 970 steel bolts	beam-to-column			Static Tests 2 tests 7/8" bolts	1. Computation of plastic moment

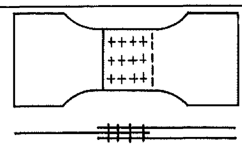
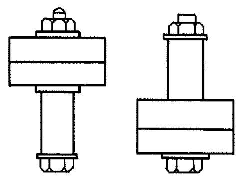
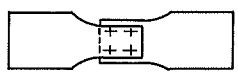
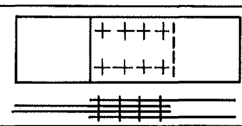
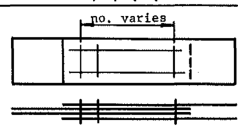
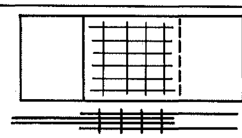
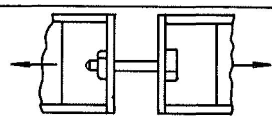
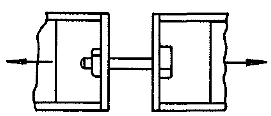
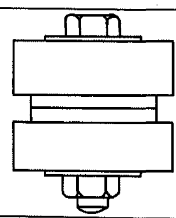
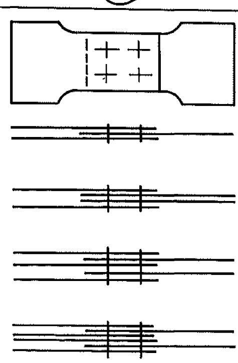
REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
152	A325 steel bolts	Butt splice		Number of bolts Tightening method Grip	Static Tension Tests 36 tests 3/4" bolt	1. Computation of coefficient of friction 2. Computation of safety factor
		Butt splice		Plate thickness Number of bolts Tightening method Grip	Static Tension Tests 12 tests 4/3" bolt 6 tests 7/8" bolt	
153	35SG steel bolts	Butt splice		Tensile load on bolts Surface preparation	Static Tension Tests 24 tests 7/8" bolts	1. Computation of coefficient of friction.
154	B.S.F. Bolts	Butt splice		Number of bolts	Static Tension Tests 9 tests 3/8" bolt HE30-WP plate	1. Computation of coefficient of friction
157	A325 steel bolts	Lap splice		Bolt diameter Surface preparation	Number of tests conducted is not reported.	1. Computation of coefficient of friction
		Joggled lap splice				
		Butt splice				
		Butt splice with liners				
163	A325 steel bolts	Test jig Calibrator	 	Bolt diameter Loading method	Direct Tension Tests 18 tests 7/8" bolt 10 tests 1" bolt 5 tests 1-1/8" bolt Torque Tension Tests 6 tests 7/8" bolt 3 tests 1" bolt 2 tests 1-1/8" bolt	
164	A141 steel rivets A325 steel bolts	(a.) box section (b.) built-up I section	(a)  (b) 	Specimen Configuration Joint size Fastener Hole preparation Rivet or Bolt pattern	Static Tension Tests (a.) 4 tests 3/4" bolt (b.) 4 tests 7/8" bolt	1. Distribution of load to pull-plate 2. Joint efficiency 3. Deformation in a joint
		(c.) Starred angle	(c) 		Static Tension Tests 8 tests 3/4" rivet 6 tests 3/4" bolt 8 tests 7/8" rivet	

REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
166	A325 steel bolts A141 steel rivets	Butt splice		Joint size Plate thickness Bolted or riveted pattern Type of holes Tension-shear ratio Surface condition Misalignment	Static Tension Tests 2 tests 3/4" bolt 4 tests 7/8" bolt	1. Computation of joint efficiencies 2. Computation of strain energy absorbed by the joints.
		Butt splice			Static Tension Tests 8 tests 3/4" bolt 4 tests 3/4" rivet	
169	A325 steel bolts	Test jig Bolt calibrator	 	Bolt diameter Grip length Thread length Loading method	Direct Tension Tests 39 tests 7/8" bolt 10 tests 1" bolt 5 tests 1-1/8" bolt Torqued Tension Tests 51 tests 7/8" bolt 3 tests 1" bolt 2 tests 1-1/8" bolt	
171	A325 steel bolts	Butt splice		Tightening method	Static Tension Tests 2 tests	1. Computation of coefficient of friction
175	A325 steel bolts	Butt splice		Joint size Number of bolts	Static Tension Tests 16 tests 7/8" bolt	1. Computation of slip coefficients. 2. Computation of joint efficiencies. 3. Computation of unbuttoning factor $U = \frac{R_{avg}}{R} = \frac{\tau_{avg}}{\tau_{ult}}$
				Joint size Plate thickness Grip length Number of bolts	Static Tension Tests 16 tests 7/8" bolt	
177	A141 steel rivets	Built-up Chord L_oU_1		Bend parameters	Static Tension Tests 3 tests of end post in truss	1. Computation of ultimate load
178	A325 steel bolts	Butt splice		Joint length Number of bolts in line	Static Tension Tests 4 tests 7/8" bolt	1. Computation load distribution in joints.

REF. NO.	CONNECTION			NOTES		
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
180	A325 steel bolts	Beam splice		Cover plate length Number of bolts	Static Tests 2 tests 3/4" bolt	1. Computation of coefficient of friction 2. Computation of plastic moment capacity
		Beam-to-column			Static Tests 4 tests 3/4" bolt	
191	A325 steel bolts	Butt splice		Joint size Number of bolts in line	Static Tension Tests 8 tests 7/8" bolt	1. Computation of theoretical ultimate load 2. Computation of slip coefficient 3. Computation of joint efficiencies 4. Computation of unbuttoning factor 5. Determination of the load partition
192	A141 steel rivets	Portion of the plate Girder flange		Location of specimen in the plate girder Joint type Grip length	Rivets gaps 16 specimens	1. Estimation of clamping force
193	A325 steel bolts	Butt splice		Bolt diameter Bolt tension	Static Tension Tests 18 tests 3/4" bolt 18 tests 1" bolt	1. Computation of coefficient of friction
194	A325 steel bolts	Test jigs	 	Nut size Nut type Loading method Lubrication	Tensile Tests Nut Striping Tests 26 tests heavy nuts 27 tests finished thick nuts Ultimate Load Tests 10 tests 3/4" bolts 6 tests 7/8" bolts 8 tests 1" bolts Torqued Tension Tests 216 tests 3/4" bolts 144 tests 7/8" bolts 216 tests 1" bolts	
195	A325 steel bolts	Beam-to-column		Bolt diameter Number of bolts End plate thickness Column stiffener thickness	Static Tests 3 tests 3/4" bolt 2 tests 7/8" bolt	1. Computation of load capacity of column web stiffeners 2. Computation of plastic moment

REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
196	B.S. 1083 bolts	Butt splice		Joint size Bolt pattern Bolt tension Number of bolt	Static Tension Tests 4 tests 5/8" bolt	1. Computation of coefficient of friction
		Beam-to-column		Number of bolts Load range Bolt tension	Cyclic Load Tests 3 tests 3/4" bolt	
199	A141 steel rivets A325 steel bolts	Butt splice		Joint size Plate thickness Pitch Number of fasteners in line Tension-shear ratio Fastener type	Static Tension Tests 5 tests 7/8" bolt 2 tests 7/8" rivet	1. Computation of theoretical ultimate load 2. Computation of unbuttoning factor 3. Determination of the load partition at ultimate
200	A325 steel bolts	Butt splice		Joint size Number of bolts in line	Static Tension Tests 4 tests 7/8" bolt	1. Computation of slip coefficient 2. Computation of unbuttoning factor
207	A141 rivet A325 bolt	Beam-to-column		Moment-shear ratio	Static Tests 3/4" rivets connecting beam web and 3/4" A325 bolts connecting column flange Static Test 1 test 3/4" rivets	1. Computation of moment-resisting capacity
217	A325 steel bolts	Test jig		Grip length Thread length Length under head Loading condition	Direct Tension Tests 32 tests 7/8" bolt Torqued Tension Tests 24 tests 7/8" bolt	
218	A325 bolt	Butt splice		Hole diameter Bolt diameter Tension-shear ratio Load range	Fatigue Tests 11 tests 3/4" bolt 1 test 5/8" bolt	1. Computation of coefficient of friction
219	9/16 in. bolts	Connecting-rod		Pretightening load		1. Computation of stresses in bolt

REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
220		Plate with hole		Plate thickness Plate width	<u>Fatigue Tests</u> 41 tests	1. Development of the relationship of endurance limit to bearing ratio
	High-strength steel bolts	Butt splice		Plate thickness Plate width Bearing ratio	<u>Fatigue Tests</u> 71 tests 1/4" bolt	
221	A141 steel rivets	Butt splice		Joint size Number of rivets in line	<u>Static Tension Tests</u> 3 tests 7/8" rivet	1. Computation of theoretical ultimate load 2. Computation of unbuttoning factor
224	A325 steel bolts	Lap splice		Joint size Number of bolts in line Tension-shear ratio	<u>Static Tension Tests</u> 4 tests 7/8" bolt	1. Computation of slip coefficient 2. Computation of unbuttoning factor
227	A354 steel bolts A325 steel bolts	Test jigs		Grip Nut size Washer and no washer Grip Threads in grip Type holders Type fastener T : S ratio Location of shear plane	<u>Relaxation Test</u> 11 tests 3/4" A354 bolt <u>Direct Tension and Torqued Tension Tests</u> of single bolts <u>Combined Tension-shear tests</u>	
229	A354BC bolts A354BD bolts	Test jig		Bolt grades Bolt head type Grip length Thread in grip Thread lubrication Loading condition	<u>Direct Tension Tests</u> 27 tests 7/8" bolt <u>Torqued Tension Tests</u> 56 tests 7/8" bolt	
230	A325 bolts	Butt splice		Type steel Number of faying surfaces	<u>Static Tension Tests</u> 18 tests 1" bolt	1. Computation of coefficient of friction
231	A325 steel bolts	Beam splice (lap plates) Beam splice		Bolt diameter Number of bolts Thickness of end plate	<u>Static Tension Tests</u> 8 tests <u>Static Tension Tests</u> 6 tests	1. Computation of bolt tension 2. Computation of plastic moment 3. Determination of prying action
		Tee stubs		Bolt diameter T-stub size Flexible or rigid abutment	<u>Static Tension Tests</u> 17 tests (a) specimen 10 tests (b) specimen	
		Beam-to-column		Beam size Bolt diameter T-stub size	<u>Static Tension Tests</u> 3 tests	

REF. NO.	CONNECTION				NOTES	
	CONNECTING MEDIUM	TYPE	SKETCH	VARIABLES	TESTS	ANALYSIS
232	A325 steel bolts	Butt splice		Patterns of misalignment	Static Tension Tests 8 tests 3/4" bolt	1. Computation of joint efficiencies 2. Computation of strain energy absorption of the joint
233	A325 steel bolts A354 steel bolts	Test jig		Bolt materials Bolt head Nut type Washer Bolt tension	Relaxation Tests Nut Tests 28 tests 3/4" A325 bolt 11 tests 3/4" A354 bolt Bolt Head Tests 12 tests 3/4" A325 bolt Head Torque Tests 4 tests 3/4" A325 bolt Lubrication Tests 2 tests 3/4" A325 bolt	
		Butt splice		Joint size Bolt diameter Nut type Washer Stress range Bolt tension	Fatigue Tests 0 to tension 19 tests 3/4" A325 bolt 1 test 1" A325 bolt 1 test 5/8" A325 bolt	1. Computation of coefficient of friction
234	A325 steel bolts	Butt splice		Plate width Bolt tension Bolt head type A_n/A_s ratio Number of washers	Static Tension Tests 6 tests 7/8" bolt A440 steel plates	1. Computation of slip coefficient 2. Computation of load portion and ultimate strength
				Number of fasteners in line Gripped material	Static Tension Tests 5 tests 7/8" bolts A440 steel plates	
				Joint width	Static Tension Tests 3 tests 7/8" bolts A440 steel plate	
236	A490 steel bolt	Test jig		Bolt length Nominal grip Thread in grip Loading method	Torqued Tension Tests 20 tests 7/8" bolt Direct Tension Tests 20 tests 7/8" bolt	
237	A490 steel bolts	Test jig		Bolt length Total grip Thread length in grip Loading method	Direct Tension Tests 21 tests 7/8" bolt Torqued Tension Tests 26 tests 7/8" bolt	
238	A325 steel bolts A354BD steel bolts	Test jig		Type of bolt Bolt length Bolt diameter Bolt hardness Grip length Test block materials Tension-shear ratio	Static Tests 86 tests 3/4" A325 bolt 10 tests 1" A325 bolt 20 tests 3/4" A354BD bolt	1. Development of empircal interaction curve for combined tension and shear
240	A325 steel bolts	Butt splice		Joint type Plate materials Plate thickness Initial bolt tension	Static Tension Tests 29 tests 1" bolt	1. Computation of coefficient of friction

8. RESEARCH COUNCIL REPORTS

GENERAL

1. RCRBSJ-Progress Report of RCRBSJ, AREA Proceedings, Vol. 51, 1950, (Abstract No. 34)

2. RCRBSJ-"NEW CONCEPTS IN STRUCTURAL JOINT DESIGN", December, 1953, (Abstract No. 65)

SPECIFICATIONS (Committee 15)

1. SPECIFICATIONS FOR ASSEMBLY OF STRUCTURAL JOINTS USING HIGH STRENGTH BOLTS
Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation, New York, N. Y., 1951

2. SPECIFICATIONS FOR ASSEMBLY OF STRUCTURAL JOINTS USING HIGH STRENGTH BOLTS
Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation, New York, N. Y., 1954

3. SPECIFICATIONS FOR STRUCTURAL JOINTS USING ASTM A325 BOLTS
Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation, New York, N. Y., 1960

4. SPECIFICATIONS FOR STRUCTURAL JOINTS USING ASTM A325 BOLTS
Journal of the Structural Division, ASCE, Vol. 88, No. ST5, Proc. Paper 3294, October, 1962, pp. 11-24

5. SPECIFICATIONS FOR STRUCTURAL JOINTS USING ASTM A325 OR A490 BOLTS
Research Council on Riveted and Bolted Structural Joints of the Engineering Foundation, New York, N. Y., March, 1964

Project I - EFFECT OF BEARING PRESSURE ON STATIC STRENGTH

1. Becker, W. K., Sinnamon, G. K., and Munse, W. H.
"THE EFFECT OF BEARING PRESSURE ON THE STATIC STRENGTH OF RIVETED JOINTS", SRS No. 8, January, 1951, (Abstract No. 42)

2. Massard, J. M., Sinnamon, G. K., and Munse, W. H.
"THE EFFECT OF BEARING PRESSURE ON THE STATIC STRENGTH OF RIVETED JOINTS", SRS No. 21, January, 1952, (Abstract No. 51)

3. Jones, J.
"EFFECT OF BEARING RATIO ON STATIC STRENGTH OF RIVETED JOINTS", Journal of the Structural Division, ASCE, Vol. 82, No. ST6, Paper 1108, November, 1956, (Abstract No. 104)

4. Chesson, E., Jr., Petersen, K. S., Bell, W., and Munse, W. H.
"STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS", University of Illinois, Urbana, January 1956, (Abstract No. 99)

5. Munse, W. H.
"THE EFFECT OF BEARING PRESSURE ON THE STATIC STRENGTH OF RIVETED CONNECTIONS", University of Illinois Experiment Station, Bulletin No. 454, July 1959, (Abstract No. 144).

Project II - (See Committee 2)

Project III - STRENGTH OF RIVETS IN COMBINED SHEAR AND TENSION

1. Higgins, T. R., and Munse, W. H.
"HOW MUCH COMBINED STRESS CAN A RIVET TAKE"?, Engineering News Record, December 4, 1952, Vol. 149, No. 23, pp. 40-42, (Abstract No. 59)

2. Chesson, E., Jr., Petersen, K. S., Bell, W. G., and Munse, W. H.
STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS, University of Illinois, Urbana, January 1956, (Abstract No. 99)

3. Munse, W. H., and Cox, H. L.
"THE STATIC STRENGTH OF RIVETS SUBJECTED TO COMBINED TENSION AND SHEAR", University of Illinois, Engineering Experiment Station, Bulletin No. 437, December 1956, (Abstract No. 108)

Project IV - STATIC AND FATIGUE TESTS OF BOLTED STRUCTURAL JOINTS

1. Hechtman, R. A.
"CONDITIONS AFFECTING THE SLIP OF STRUCTURAL STEEL BOLTED JOINTS", The Trend in Engineering, University of Washington, Vol. 1, No. 4, October 1949, pp. 12-18. (Abstract No. 26)

2. Munse, W. H., Schutz, F. W., and Cox, H. L.
"STATIC AND FATIGUE TESTS OF BOLTED STRUCTURAL LAP JOINTS", SRS No. 3, Dept. of Civil Engineering, University of Illinois, Urbana, July 1950. (Abstract No. 31)

3. Wilson, W. M.
"HIGH-STRENGTH BOLTS AS A MEANS OF FABRICATING STEEL STRUCTURES", Proceedings, Highway Research Board, University of Illinois, December, 1950, pp. 136-143. (Abstract No. 32)

4. Wright, D. T., and Munse, W. H.
"CALIBRATION TESTS OF HIGH-STRENGTH BOLTS", Dept. of Civil Engineering, University of Illinois, SRS No. 9, January, 1951, (Abstract No. 41)

5. Young, D. R., and Hechtman, R. A.
"SLIP OF STRUCTURAL STEEL DOUBLE-LAP JOINTS ASSEMBLED WITH HIGH-STRENGTH BOLTS", The Trend in Engineering, Part I in April 1951, pp. 24-27, and Part II in July, 1951, pp. 23-26. (Abstract No. 43)

6. Wright, D. T., and Munse, W. H.
"STATIC TESTS OF BOLTED AND RIVETED JOINTS", Dept. of Civil Engineering, University of Illinois, SRS No. 20, January, 1952. (Summarized in LABORATORY TESTS OF BOLTED JOINTS, by W. H. Munse, D. T. Wright, and N. M. Newmark, Transactions, ASCE, Vol. 120, Paper No. 2778, 1955, pp. 1299-1318). Abstract No. 53.

7. Fuller, J. R., and Munse, W. H.
"LABORATORY TESTS OF STRUCTURAL JOINTS WITH OVER-STRESSED HIGH TENSILE STEEL BOLTS", Dept. of Civil Engineering, University of Illinois, SRS No. 44, January 1953. (Abstract No. 63)

8. Leahey, T. F., and Munse, W. H.
"STATIC AND FATIGUE TESTS OF RIVETS AND HIGH-STRENGTH BOLTS IN DIRECT TENSION", Dept. of Civil Engineering, University of Illinois, SRS No. 80, July, 1954. (Abstract No. 74)

9. Beam, W. S., and Munse, W. H.
"EFFECTS OF REPEATED LOADINGS ON STRUCTURAL CONNECTIONS WITH HIGH-STRENGTH BOLTS", Dept. of Civil Engineering, University of Illinois, SRS No. 91, January, 1955. (Abstract No. 79)

10. Hechtman, R. A., Flint, T. R., and Koepsell, P. L.
"FIFTH PROGRESS REPORT ON SLIP OF STRUCTURAL STEEL DOUBLE-LAP JOINTS ASSEMBLED WITH HIGH-TENSILE STEEL BOLTS, Dept. of Civil Engineering, University of Washington, Seattle, February 1955. (Abstract No. 81)

11. Fuller, J. R., Leahey, T. F., and Munse, W. H.
"A STUDY OF THE BEHAVIOR OF LARGE I-SECTION CONNECTIONS", Proceedings, ASCE, Vol. 81, Sep. No. 659, April 1955. (Distributed by the Dept. of Civil Engineering, University of Illinois, as SRS No. 97, 1955. Appeared first as STATIC TENSILE TESTS OF I-SECTION CONNECTIONS, Dept. of Civil Engineering, University of Illinois, SRS No. 68, January 1954). (Abstract No. 82)

12. Munse, W. H., Wright, D. T., and Newmark, N. M.
"LABORATORY TESTS OF BOLTED JOINTS", Transactions, ASCE, Vol. 120, Paper No. 2778, 1955, pp. 1299-1318. (Appeared as LABORATORY TESTS OF HIGH TENSILE BOLTED STRUCTURAL JOINTS, Proceedings, ASCE, Vol. 80, Separate No. 441, May 1954). (Abstract No. 92).

13. Hechtman, R. A., Young, D. R., Chin, A. G., and Savikko, E. R.
"SLIP OF JOINTS UNDER STATIC LOADS", Transactions, ASCE, Vol. 120, Paper No. 2778, 1955, pp. 1335-1352. (Appeared first in Proceedings, ASCE, Vol. 80, Separate No. 484, August 1954. This report summarizes the material reported in Progress Reports 1, 2, and 3 "ON SLIP OF STRUCTURAL STEEL DOUBLE LAP JOINTS ASSEMBLED WITH HIGH STRENGTH BOLTS TO RCRBSJ", University of Washington, January 1951, 1952, and 1953). (Abstract No. 96).

14. Chesson, E., Jr., Petersen, K. S., Bell, W., and Munse, W. H.
"STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS", University of Illinois, Urbana, January 1956. (Abstract No. 99).

15. Madison, R. B., and Vasarhelyi, D. D.
"THE BEHAVIOR OF BOLTED JOINTS WITH MISALIGNED PUNCHED HOLES AND PAINTED FAYING SURFACES AT ROOM AND SUB-ZERO TEMPERATURE", Dept. of Civil Engineering, University of Washington, Sixth Progress Report, June 1956. (Summarized in EFFECTS OF FABRICATION TECHNIQUES, by D. D. Vasarhelyi, S. Y. Beano, R. B. Madison, Z. A. Lu, and U. C. Vasishth, Transactions, ASCE, Vol. 126, Part II, 1961, pp. 764-796). (Abstract No. 101)

16. Petersen, K. S., and Munse, W. H.
"STATIC TENSION TESTS OF RIVETS AND HIGH STRENGTH BOLTS IN STRUCTURAL CONNECTIONS", Dept. of Civil Engineering, University of Illinois, SRS No. 124, November, 1956. (Abstract No. 103)

17. Munse, W. H.
"RESEARCH ON BOLTED CONNECTIONS", Transactions, ASCE, Vol. 121, Paper No. 2839, 1956, pp. 1255-1266. (Appeared first as BOLTED CONNECTIONS RESEARCH, Proceedings, ASCE, Separate No. 650, March 1955. Distributed by Dept. of Civil Engineering, University of Illinois, as SRS No. 94, 1955). (Abstract No. 107).

18. Lu, Z. A., Vasishth, C., and Vasarhelyi, D. D.
"TESTS OF LARGE BOLTED JOINTS TIGHTENED BY THE ONE-TURN-OF-THE-NUT METHOD", Dept. of Civil Engineering, University of Washington, Seattle, Seventh Progress Report to RCRBSJ, January 1957. (Summarized in EFFECTS OF FABRICATION TECHNIQUES, Transactions, ASCE, Vol. 126, Part II, 1961, pp. 764-796). (Abstract No. 110).

19. Vasishth, U. C., Lu, Z. A., and Vasarhelyi, D. D.
"A STUDY OF THE NOMINAL COEFFICIENT OF FRICTION IN STRUCTURAL STEEL JOINTS FASTENED BY HIGH TENSILE BOLTS", Dept. of Civil Engineering, University of Washington, Eighth Progress Report to RCRBSJ, June 1957. (Summarized in EFFECTS OF FABRICATION TECHNIQUES, Transactions, ASCE, Vol. 126, Paper No. 1973, 1961, pp. 764-796). (Abstract No. 120)

20. Munse, W. H., and Chesson, E., Jr.
"SUMMARY-INVESTIGATION OF HIGH-TENSILE BOLTS AND BOLTED CONNECTIONS", University of Illinois, Urbana, November 1959. (Abstract No. 162)

21. Munse, W. H., and Chesson, E., Jr.
"THE EFFECT OF METHOD OF TIGHTENING ON THE SLIP BHEAVIOR OF BOLTED JOINTS", Dept. of Civil Engineering, University of Illinois, Urbana, Illinois, November 1959. (Abstract No. 171)

22. Munse, W. H., Petersen, K. S., and Chesson, E., Jr.
"STRENGTH IN TENSION", Transactions, ASCE, Vol. 126, Part II, Paper No. 3241, 1961, pp. 700-728. (Appeared in Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paper 1970, March 1959, pp. 7-28. Original paper appeared as STATIC TENSION TESTS OF RIVETS AND HIGH-STRENGTH BOLTS IN STRUCTURAL CONNECTIONS, Dept. of Civil Engineering, University of Illinois, SRS No. 124, November 1956). (Abstract No. 203)

23. Knoell, A. C., Chesson, E., Jr., and Munse, W. H.
"FATIGUE BEHAVIOR OF BOLTED JOINTS ASSEMBLED WITHOUT WASHERS", Dept. of Civil Engineering, University of Illinois, SRS No. 242, February, 1962. (Abstract No. 218)

24. Chesson, E., Jr., and Munse, W. H.
"STUDIES OF THE BEHAVIOR OF HIGH-STRENGTH BOLTS AND BOLTED JOINTS", Dept. of Civil Engineering, University of Illinois, Urbana, December 1963. (Abstract No. 233)

Project V - EFFECT OF GRIP ON THE FATIGUE STRENGTH OF RIVETED AND BOLTED JOINTS

1. Baron, F., and Larson, E. W., Jr.
"THE EFFECT OF GRIP ON THE FATIGUE STRENGTH OF RIVETED AND BOLTED JOINTS", AREA Bulletin No. 503, September-October 1952. (Abstract No. 58)

2. Baron, F., and Larson, E. W., Jr.
"COMPARISON OF BOLTED AND RIVETED JOINTS", Transactions, ASCE, Vol. 120, Paper No. 2778, 1955, pp. 1322-1334. (Appeared as COMPARATIVE BEHAVIOR OF BOLTED AND RIVETED JOINTS, Proceedings, ASCE, Vol. 80, Sep. No. 470, August 1954. Also appeared as Research Report C109, Northwestern University, 1952). (Abstract No. 95)

Project VI - (See Committee 13)

Project VII - EFFECT OF RIVET PATTERN UPON THE FATIGUE STRENGTH OF STRUCTURAL JOINTS

1. Lenzen, K. H.
"THE EFFECT OF VARIOUS FASTENERS ON THE FATIGUE STRENGTH OF A STRUCTURAL JOINTS", AREA Bulletin, No. 480, June-July 1949. (Abstract No. 24)

2. Baron, F., Larson, E. W., Jr., and Kenworth, K. J.
"THE EFFECT OF CERTAIN RIVETED PATTERNS ON THE FATIGUE AND STATIC STRENGTH OF JOINTS", Research Council on Riveted and Bolted Structural Joints, February 1955. (Abstract No. 80).

Project VIII - (See Committee 7)

Committee 1 (I) - EFFECT OF BEARING PRESSURE ON FATIGUE

1. Lewitt, C. W., Chesson, E., Jr., and Munse, W. H.
"THE EFFECT OF RIVET BEARING ON THE FATIGUE STRENGTH OF RIVETED JOINTS", University of Illinois, SRS No. 170, January 1959. (Abstract No. 138)

2. Chesson, E., Jr., Lewitt, C. W., Dineen, R. L., and Munse, W. H.
"STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS, University of Illinois, Urbana, January 1959. (Abstract No. 139)

3. Chu, T. Y.
"THE EFFECT OF BEARING STRESSES ON THE FATIGUE STRENGTH OF A STRUCTURAL JOINT", M. S. Thesis, University of Kansas, Lawrence, Kansas, May 1962. (Abstract No. 220)

4. Lewitt, C. W., Chesson, E., Jr., and Munse, W. H.
"RIVETED AND BOLTED JOINTS:FATIGUE OF BOLTED CONNECTIONS, Journal of the Structural Division, ASCE, Vol. 89, No. ST1, February 1963.

Committee 2 (II) - EFFECT OF FASTENER PATTERNS ON THE STATIC STRENGTH

1. Wilson, W. M., Munse, W. H., and Cayci, M. A.
"A STUDY OF THE PRACTICAL EFFICIENCY UNDER STATIC LOADING OF RIVETED JOINTS CONNECTING PLATES", University of Illinois, Engineering Experiment Station, Bulletin No. 402, July 1952. (Abstract No. 55)

2. Shultz, F. W., Jr., and Newmark, N. M.
"THE EFFICIENCY OF RIVETED STRUCTURAL JOINTS, (SRS No. 30), September 1952. (Abstract No. 56)

3. (No Author)
"HERE'S A BETTER WAY TO DESIGN SPLICES", Engineering News Record, Vol. 150, Part I, January 8, 1953, pp. 41-42, (Abstract No. 62)

4. Chesson, E., Jr., Petersen, K. S., Bell, W. G., and Munse, W. H.
"STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS", University of Illinois, Urbana, January 1956. (Abstract No. 99).

5. Chesson, E., Jr., and Munse, W. H.
"BEHAVIOR OF RIVETED TRUSS-TYPE CONNECTIONS", Transactions, ASCE, Vol. 123, 1958, pp. 1087-1128. (Appeared as A STUDY OF THE BEHAVIOR OF RIVETED CONNECTIONS IN TRUSS-TYPE MEMBERS, Journal of the Structural Division, ASCE, Vol. 83, No. ST1, Proc. Paper No. 1150, January 1957. Distributed by University of Illinois first as SRS No. 132, 1957. Greater detail is given in SRS No. 115, January, 1956). (Abstract No. 132)

6. Chesson, E., Jr., Lewitt, C. W., Dineen, R. L., and Munse, W. H.
"STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS", University of Illionis, Urbana, January 1959. (Abstract No. 139)

7. Chesson, E., Jr., and Munse, W. H.
"BEHAVIOR OF LARGE RIVETED AND BOLTED STRUCTURAL CONNECTIONS", Dept. of Civil Engineering, University of Illinois, Urbana, SRS No. 174, 1959. (Summarized in RIVETED AND BOLTED JOINTS: TRUSS-TYPE CONNECTIONS, by Chesson, and Munse, Journal of the Structural Division, ASCE, Vol. 89, No. ST1, Proc. Paper No. 2412, February 1963, pp. 66-106). (Abstract No. 164)

8. Chesson, E., Jr., and Munse, W. H.
"RIVETED AND BOLTED JOINTS:TRUSS-TYPE TENSILE CONNECTIONS, Journal of the Structural Division, ASCE, Vol. 89, No. ST1, pp. 67-106, 1963

9. Munse, W. H., and Chesson, E., Jr.
"RIVETED AND BOLTED JOINTS:NET SECTION DESIGN", Journal of the Structural Division, ASCE, Vol. 89, No. ST1, pp. 107-126, 1963.

Committee 3 - BOLTS UNDER COMBINED TENSION AND SHEAR

1. Stafford, R. W., Lewitt, C. W., and Chesson, E., Jr.
"PRELIMINARY TESTS OF HIGH STRENGTH BOLTS UNDER COMBINED SHEAR AND TENSION", University of Illinois, Urbana, February 1959. (Abstract No. 141)

2. Munse, W. H., Petersen, K. S., and Chesson, E., Jr.
"STRENGTH IN TENSION", Transactions, ASCE, Vol. 126, Part II, Paper No. 3241, 1961, pp. 700-728. (Appeared in Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paper 1970, March 1959, pp. 7-28. Original paper appeared as STATIC TENSION TESTS OF RIVETS AND HIGH-STRENGTH BOLTS IN STRUCTURAL CONNECTIONS, Dept. of Civil Engineering, University of Illinois, SRS No. 124, November 1956). Abstract No. 203)

3. Chesson, E., Jr., and Munse, W. H.
"STATUS REPORT OF PRELIMINARY STUDIES COMPARING A354 AND A325 HIGH STRENGTH BOLTS, Dept. of Civil Engineering, University of Illinois, August 1962. (Abstract No. 227)

4. Chesson, E., Jr., Faustino, N. L., and Munse, W. H.
"STATIC STRENGTH OF HIGH-STRENGTH BOLTS UNDER COMBINED TENSION AND SHEAR", Dept. of Civil Engineering, University of Illinois, March, 1964. (Abstract No. 238)

Committee 4 - EVALUATION OF NUTS

1. Krickenberger, C. F., Jr., Chesson, E., Jr., and Munse, W. H.
"EVALUATION OF NUTS FOR USE WITH HIGH STRENGTH BOLTS", Dept. of Civil Engineering, University of Illinois, SRS No. 128, January, 1957. (Abstract No. 109)

2. Viner, J. G., Dineen, R. L., Chesson, E., Jr., and Munse, W. H.
"A STUDY OF THE BEHAVIOR OF NUTS FOR USE WITH HIGH-STRENGTH BOLTS", Dept. of Civil Engineering, University of Illinois, SRS No. 212, April, 1961. (Abstract No. 194)

Committee 5 - BEAM TO COLUMN CONNECTIONS

1. Chesson, E., Jr., Lewitt, C. W., Dineen, R. L., and Munse, W. H. "STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS", University of Illinois, Urbana, January 1959. (Abstract No. 139).

2. Bell, W. G., Chesson, E., Jr., and Munse, W. H. "BEHAVIOR OF RIVETED AND BOLTED BEAM-TO-COLUMN CONNECTIONS, Journal of the Structural Division, ASCE, Vol. 85, No. ST3, Proc. Paper 1971, March 1959, pp. 29-50. (Appeared as STATIC TESTS OF STANDARD RIVETED AND BOLTED BEAM-TO-COLUMN CONNECTIONS, Dept. of Civil Engineering, University of Illinois, Urbana, SRS No. 146, January 1958). (Abstract No. 207).

Committee 6 - SLIP OF BOLTED BRIDGE JOINTS

Committee 7 (VIII) - CUMULATIVE DAMAGE

1. Chesson, E., Jr., Petersen, K. S., Bell, W. G., and Munse, W. H. "STATUS REPORT ON RIVETED AND BOLTED STRUCTURAL JOINTS", University of Illinois, Urbana, January 1956. (Abstract No. 99).

2. Munse, W. H., Fuller, J. R., and Petersen, K. S. "CUMULATIVE DAMAGE IN STRUCTURAL JOINTS", AREA Bulletin No. 544, June-July 1958. p. 67. (Abstract No. 130)

Committee 8 (IV) - BEARING AREA REQUIREMENTS UNDER BOLT HEADS

1. Lewitt, C. W., Chesson, E., Jr., and Munse, W. H. "PRELIMINARY REPORT ON RELAXATION STUDIES OF HIGH-STRENGTH BOLTS", Dept. of Civil Engineering, University of Illinois, October 1959. (Abstract No. 170)

2. Lewitt, C. W., Chesson, E., Jr., and Munse, W. H. "STUDIES OF THE EFFECT OF WASHERS ON THE CLAMPING FORCE IN HIGH-STRENGTH BOLTS", Dept. of Civil Engineering, University of Illinois, SRS No. 191, March 1960. (Abstract No. 174)

Committee 9 - STATIC STRENGTH OF BOLTED STRUCTURAL JOINTS

1. Foreman, R. T., and Rumpf, J. L. "STATIC TENSION TESTS OF BOLTED JOINTS", Progress Report No. 1, Fritz Engineering Laboratory Report No. 271.1, Lehigh University, Bethlehem, Pa., December 1958. (Abstract No. 133)

2. Rumpf, J. L. "FURTHER STATIC TENSION TEST OF BOLTED JOINTS", Fritz Engineering Laboratory Report No. 271.2, Lehigh University, Bethlehem, Pa., December 1958. (Abstract No. 136)

3. Rumpf, J. L. "SHEAR RESISTANCE OF HIGH STRENGTH BOLTS", Fritz Engineering Laboratory Report No. 271.3, Lehigh University, December 1958. (Abstract No. 137)

4. Kaplan, S.
"DOUBLE SHEAR TEST OF HIGH STRENGTH BOLTS", Fritz Engineering Laboratory Report 271.4, Lehigh University, April 1959. (Abstract No. 142)

5. Bendigo, R. A.
"BOLT CALIBRATION STUDY", Fritz Engineering Laboratory Report No. 271.5, Lehigh University, June 1959. (Abstract No. 163).

6. Bendigo, R. A., and Rumpf, J. L.
"CALIBRATION AND INSTALLATION OF HIGH STRENGTH BOLTS", Fritz Engineering Laboratory Report No. 271.7, Lehigh University, September 1959. (Abstract No. 169)

7. Bendigo, R. A., and Rumpf, J. L.
"STATIC TENSION TEST OF LONG BOLTED JOINTS", Fritz Engineering Laboratory Report No. 271.8, Lehigh University, February 1960. (Abstract No. 175)

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Committee 19 - COLD DRIVEN RIVETS

Committee 20 - INSTALLATION OF BOLTS

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11. APPENDIXES

1. OBJECTIVES OF RESEARCH COUNCIL ON RIVETED AND BOLTED STRUCTURAL JOINTS

Because it is generally recognized that current practices in the design of riveted and bolted connections have been developed empirically and that many of these practices and the joint capacities predicted therewith are not supported by scientific data, the Research Council on Riveted and Bolted Structural Joints has been organized to carry on investigations to determine the suitability and capacity of various types of joints used in fabricated structural frames. It is expected that the Council's work will result in the promulgation of more economical and efficient practices[a].

2. CHAIRMAN OF THE RESEARCH COUNCIL

T. R. Higgins	1947-1950
W. C. Stewart	1950-1954
E. J. Ruble	1954-1958
E. L. Erickson	1958-1961
R. B. Belford	1961-1965

3. CURRENT AND PAST MEMBERS OF THE RESEARCH COUNCIL

+R. Archibald, Alaska Dept. of Highways (Ret.)
*R. W. Arner, Pennyslvania Dept. of Highways
E. F. Ball, Bethlehem Steel Co.
*B. A. Bakhmeteff, Columbia University
R. B. Banks, Northwestern University
+F. Baron, University of California
+D. C. Beam, Canadian Inst. of Steel Construction
J. L. Beckel, New York Central Railroad
+L. S. Beedle, Lehigh University

a Based on statement appearing in abstract 34.

+R. B. Belford, Industrial Fasteners Institute
D. F. Bolton, Bureau of Public Roads
+J. E. Burke, Illinois Dept. of Highways
J. W. Carter, The Glen L. Martin Co.
*W. E. Chastain, Illinois Dept. of Highways
+E. Chesson, Jr., University of Illinois
J. S. Davey, Russell, Burdsall & Ward Bolt and Nut Co.
+F. H. Dill, American Bridge, U. S. Steel
R. E. Davis, University of California
W. J. Disher, Disher Steel Construction Co., Ltd.
+F. P. Drew, Association of American Railroads.
C. A. Ellis, Northwestern University
+S. Epstein, Bethlehem Steel Co.
+E. L. Erickson, Bureau of Public Roads
+E. R. Estes, Jr., Florida Steel Corp.
+F. B. Farquharson, University of Washington
+J. W. Fisher, Lehigh University
+E. T. Franzen, CRI and P Railroad
+E. H. Gaylord, University of Illinois
+J. Giliberto, U. S. Army Mobility Command
*H. C. Graham, Screw and Bolt Corp. of America
+F. E. Graves, Russell, Burdsall & Ward Bolt & Nut Co.
+E. C. Hartmann, Aluminum Co. of America
+N. G. Hansen, Corp. of Engineers
+R. M. Hansen, Lamson and Sessions Co.
C. P. Hazelet, Hazelet and Erdal
+R. A. Hechtman, Consultant
+T. R. Higgins, American Institute of Steel Constr.
+F. Hobbs, Federal Bolt and Nut Corp., Ltd.
L. G. Holleran, Clark, Rapuano and Holleran
+ W. S. Hyler, Battelle Memorial Institute
+L. K. Irwin, National Bureau of Standards
+B. G. Johnston, University of Michigan
+K. H. Jensen, Pennsylvania Dept. of Highways
*J. Jones, Bethlehem Steel Co.
+F. Kellam, Indiana Dept. of Highways
E. F. Kelley, Bureau of Public Roads
J. J. Kelley, Screw and Bolt Corp. of America
+E. Kirkendall, The Engineering Foundation
+W. G. Kirkland, American Iron & Steel Institute
E. W. Larson, Jr., Northwestern University
+K. H. Lenzen, University of Kansas
H. H. Lind, Industrial Fasteners Institute
F. H. Lovell, Pennsylvania Railroad
+G. M. Magee, Association of American Railroads
+S. W. Marras, Fasteners Research Council
+A. S. Marvin, American Bridge - U. S. Steel
+N. P. Maycock, The Steel Co. of Canada, Ltd.
*G. A. Maney, Northwestern University
*J. P. Matte, Jr., Albert Kahn Assoc.
+L. B. McCammon, National Engineering Science Co.
+W. A. Milek, American Institute of Steel Constr.

C. W. Muhlenbruch, Northwestern University
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V. M. Romine, Illinois Dept. of Highways
+E. J. Ruble, Association of American Railroads
+J. L. Rumpf, Drexel Inst. of Technology
C. H. Sandberg, A. T., and S. F. Railway
+A. L. R. Sanders, Hazelet and Erdal
+F. W. Schutz, Jr., Georgia Inst. of Technology
+A. Schwartz, Jr., Bethlehem Steel Co.
*T. C. Shedd, University of Illinois
+C. F. Sheffey, Bureau of Public Roads
F. T. Sisco, The Engineering Foundation
+A. M. Smith, The Lamson and Sessions Co.
+T. W. Spilman, Bethlehem Steel Co.
*W. C. Stewart, Industrial Fasteners Institute
+D. L. Tarlton, Canadian Inst. of Steel Const.
+D. D. Vasarhelyi, University of Washington
+G. S. Vincent, Bureau of Public Roads (Ret.)
+R. J. Wagner, Screw and Bolt Corp. of America
+A. V. Walker, Bureau of Public Roads
C. E. Webb, American Bridge, U. S. Steel
*W. M. Wilson, University of Illinois
B. L. Wood, Consulting Engineer
G. B. Woodruff, Consulting Engineer
L. T. Wyly, Northwestern University

*Deceased
+Active Members

4. SOME NOTES ON THE RESEARCH COUNCIL SPECIFICATIONS

1951

The Research Council, formed in 1947, approved its first specification on January 31, 1951, after examining the results of the research it planned and sponsored on high-strength bolts. The reliability of structural joints fastened by high-strength bolts had been demonstrated in field tests performed by the Association of American Railroads under actual operating conditions and in laboratory investigations. This initial specification allowed the replacement of A141 steel rivets with A325 bolts of the same nominal diameter. Additional details are given in Ref. 44 and 48.

1954

Because the initial specification was prepared while research was still in progress, it was necessarily conservative. On February 27, 1954, the Research Council approved a revised specification based on further laboratory and field experience. Among the changes was permission to use flat washers on wide-flange beams with a 1:20 sloping flange. Painting of the faying surface was approved for joints in which slip into bearing was permissible. The installation procedure with impact wrenches was modified. In recommending that bolt tension be set 15% above the minimum tension the Council recognized that torque measurement is not a dependable means of determining bolt tension. Also, the inspection procedures were relaxed because of the dependability of the high-strength bolt.

1955

As a result of questions by users of the specification, the Research Council provided authoritative guidance in an Appendix on December 15, 1955. Also, as a result of studies of installation methods[66,84,85], the Council endorsed the one-turn-of-nut-from-hand-tight method as a satisfactory method of tension control.

1960

In March 1960 a new edition of the specification was issued which recognized the greater strength of joints connected by high-strength bolts. Up to 1960 the accepted design practice was direct substitution of bolts for rivets of equal size. However, the Council had accumulated sufficient data to permit establishment of an adequate design practice for bolted joints. Two different designs were allowed, friction-type connections and bearing-type connections. Designers could take full advantage of the higher-strength bolts, and allowable bolt stresses were increased 45%. A newly designed heavy-hexagon structural bolt with a larger head and shorter thread length was approved. Tightening procedures were clarified and the minimum bolt tension was increased to the bolt proof load. Installation by the turn-of-nut method was modified and reliance on torque measurement as a means of determining bolt tension was discouraged by the elimination of all torque information. The required size of hardened washers was reduced and the omission of the washer under the bolt head or nut (whichever was not being turned in tightening) was permitted. A commentary similar to the 1955 Appendix was added to interpret many of the requirements and furnish the user with reference data. Comments related to this specification are given in Refs. 183, 185, and 186.

<u>1962</u>

In March 1962, a revised specification was adopted which clarified and modified the 1960 edition. Bolts installed by the turn-of-nut method were no longer required to have washers under either bolt head or nut. Also, research had indicated that 1/2-turn-of-nut after proper snugging was sufficient to load the bolt beyond the minimum tension regardless of size or length. An additional quarter turn was required for each bevel surface (1:20) when bevel washers were not used. The heavy-hex structural bolt was adopted as standard, while the regular semi-finished hex bolts were accepted as substitutes. In addition, special-type fasteners were sanctioned provided certain criteria were satisfied. Additional discussion of the 1962 specification is given in Ref. 225.

<u>1964</u>

The latest Council specification was adopted in March 1964. It incorporates the results of additional research and is applicable to both A325 and A490 bolts. Most of the research since 1962 was conducted to develop a higher-strength bolt for use with high-strength steels. In making the specification applicable to both A325 and A490 bolts it was necessary to modify existing practice for uniformity. The required size of hardened washers was further reduced because their primary function is to provide a non-galling surface. Washers are required under both the nut and bolt head when the A490 bolt is used with A7 or A36 steel and under the turned element in higher-strength steels. Installation by the turn-of-nut method was again modified because tests[229,237,239] had shown that long A490 bolts require a greater nut rotation to produce the required minimum tension. Although the A325 bolt does not need the additional rotation, the same provision was applied in the interest of uniformity in field practice. A new section included in the specification defines the inspection procedure recommended by the Research Council.

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KEY WORDS: aluminum; bibliography; bolts; connections; rivets; steel; structural engineering; testing