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For Presentation of Connection Tests in the Welding Convention in Chicago

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26-29-54-54

Note:

The above requires about 22 slides. This number may be more than can be handle in a 20 min. presentation. I left out all stress distribution. It's too much and not all could be presented.

Plan on no more than 2000 words. 205C.7

T. Topractsoglou

AMERICAN WELDING SOCIETY
Thirty-first Annual Meeting

Paper on

"Connections for Welded Rigid Portal Frames"
(Wednesday, October 25, 1950)

Gentlemen,

The research on Connections for Welded Rigid Frames which I shall report to you is a part of a project on Welded Continuous Frames being carried out at Lehigh University in the Department of Civil Engineering ~~dep~~ and Mechanics. The objectives of the project in general are the study of the carrying capacities of welded continuous frames. But before the frames themselves are studied it was thought advisable to study the component parts of frames, namely beams, columns and connections. What I shall report to you ~~is part of~~ are the results ~~obtained on~~ of connection tests.

The project ~~was~~ is sponsored by the Welding Research Council, with financial support from the Bureau of Yards and Docks, Bureau of Ships, Office of Naval Research, AISI and the American Institute of Steel Construction. The project was under the guidance and supervision of the Lehigh Project Subcommittee. The authors of this paper extend their appreciation to the members of this committee. The 8B13 rolled section used in the tests was donated by Lehigh Structural Steel Co. of Allentown, Pennsylvania.

Take out or put at the end.

Figure 1 shows some typical rigid frames for which welding is feasible. In these structures the various members are connected with rigid connection, thus compelling the columns and beams to work together in resisting the external loads. In the single span frame (portal frame) the connection is often called a "knee". ~~column and the beam are joined together with a knee.~~ ~~Multi-span frames have knees at each end and interior connecting elsewhere.~~

Fig 5 is too small, don't you think?

~~The connections in the frames could be bolted, riveted and welded. The knees which were tested are welded. (Fig. 5) In this figure you see~~ The various types of knees, ~~i.e., the~~ may be square, bracketed and curved. ~~The different arrangements in stiffeners in the built-up knee result in these various types in the three categories.~~ These knees have been either extensively used in practice or have been suggested by the committee members or have been obtained from a literature survey.

A number of each type were selected, the principal objective being to determine the influence of various structural details on ~~that~~ behavior

Refer to Figs 17, 18?

I have stated above that the connections that have been tested are rigid knees. What do we exactly mean by rigid knee? The designer in analyzing rigid frames considers the angle formed by the centerlines of column and beam remaining constant as the structure deflects. But the knee is not a mathematical point. It is a part of the structure; it starts where the rolled sections end. The knee in transferring stresses from one member to the other is subject to deformation (rotations). It is the amount of rotations in the knee which decide whether or not the knee is rigid.

Therefore, it is of importance that we briefly review ~~in short~~ the requirements for knees. (Fig. 9 and 10). In Figure 10, curve A gives the moment-rotation curve ~~of the weaker~~ of the rolled sections joined by the knee. The early part is the elastic part in which rotations are proportional to moments; then we have the elasto-plastic, and finally the totally plastic parts in which the section is completely plastic. The moment at this stage gives the "plastic hinge value, M_p" of the section.

don't complicate it in the talk.

X

This curve is compared to the moment-rotation curve of three knees (B, C, and D); knee B, for the same moment shows larger rotations than the rolled section and the maximum moment is smaller than the plastic hinge value of the beam.

We shall call knee B unsatisfactory. On the other hand, knee C is satisfactory. Knee D, although rigid enough, does not carry the maximum moment through large rotation and it will also be considered unsatisfactory. if, in practice, large rotations would be required. Ⓐ

The curves B, C and D are obtained by dividing the total rotation of the knee by the "equivalent length" of each knee. Such lengths are shown in Figure 9. This should be earlier

So, in order to be considered as satisfactory knees must be (a) rigid, that is, have rotations less than those of the rolled section; (b) strong, that is, must develop the plastic hinge value of the rolled section. As engineers, ~~however~~, we are also interested in cost. The connection should have the proper strength and rigidity with the least amount of material and labor. Consequently, a third requirement is economy. A fourth requirement, which is of special importance in plastic design, is the ability of the knee to carry the maximum moment through large rotations. In summary, the M-ϕ characteristic must be "adequate"

The knees which were tested are shown in these two slides (Figs. 17 and 18). Those labelled A to N have an 8B13 rolled section for both legs. Connection P consists of 8WF 31 as column, and 14WF 30 as beam.

Load lines were studied to obtain an idea on how the connections should be tested. of lesser importance perhaps? Figure 19 gives some of the frames and load lines studied. In (a) and (b) with gravity loads the knees are subject to "compression." In (c) the single lateral force gives the load line shown. Here the left knee is under "tension", but such "tension" loadings occur very seldom under the combined effect of gravity and lateral loadings. In (d) the left knee is under tension. Note, however, the extraordinary dimensions of this frame. It was decided, therefore, to load the specimens in compression. and to have equal arms. ~~Also used identical~~ Ⓒ

Specimens A to N were tested either in a 300,000 lb. hydraulic machine or in a 800,000 lb. screw type machine. Figure 21 shows the test set-up in the 300,000 lb. machine. The load was applied through a loading fixture. ~~This fixture was~~ used in all tests. except ~~that was 14 x 8~~ P (14"x8") ~~connection test (A to N).~~ ~~A deflection gage used to measure deflections was~~

Ⓐ The basis for this reasoning is that the connection should be "as good" as the rolled sections joined.
~~It was the equivalent length~~

Ⓒ Say something about "worst loading". Studies on knees with straight & curved haunches

The principal measurements were those of rotation in the knee for which level bars ~~[illegible]~~ were used. Overall deflection was determined with a dial gage and SR-4's were

supported as shown. ~~Level bars were used to measure the total rotation in the knee.~~ SR-4 gages were mounted at a few critical points, ~~to measure strains.~~ The connections were laterally supported as shown. — 27 is better. Do you have one even better somewhere?

Fig. (22) shows the test set-up in the 800,000 lb. machine. In this figure note the lateral support and the SR-4 gages to measure lateral forces. The level bars and the deflection gage support can also be seen. A mirror gage was used to measure the increase in moment arm of the external load as the legs deflected.

Figure 23 shows the test set-up for Connection P. The loads were applied with a hydraulic jack and measured with a dynamometer using SR-4 equipment. Both lateral and Longitudinal supports were provided. 10/10/50 Ltr

I have previously mentioned the requirements for rigid connections (Strength, Rigidity, and Economy). Let us now see whether or not the various connections meet these requirements. Examine Connection P. Figure 38 gives the total rotation in the knee and compares it to the rotations of the two rolled sections joined by the knee. Obviously this connection does not meet the rigid knee requirements. At all stages of loading its rigidity is ~~smaller~~ less than that of 8WF31, the weaker of the two section. Moreover, it did not develop the plastic hinge value M_p = 1190 kips; it is not strong enough. Figure 41 shows the distortions in the connection at the end of the test. Why have the requirements of strength and rigidity not been met? ~~The simplest answer is: Because~~ The web was not sufficiently thick and ~~shear~~ yield is due to shearing force occurred ~~took place~~ in the web of the knee before bending yield occurred outside the knee. ⟵ (B)

This knee is unsatisfactory even for elastic design. ~~because before~~ prior to reaching a stress of 20 ksi ~~is reached~~ at the critical section a-a yielding takes place in the knee? prior?? and as you see the curves start deviating from a straight line.

Factor of safety = 1.0 is better.

The behavior of the Connections A to N ~~can best be studied with~~ is illustrated in Figure 51. In this figure the moment at the knee (center of knee) is plotted against the rotation in the knee divided by the equivalent length. When the various knee curves

(B) Note that survey of various ~~[illegible]~~ rolled sections was ~~[illegible]~~ made. Behavior of 14WF30 is not unusual.

are compared to 8B13, rolled section used, one can see that all of the connections developed in the knee itself the plastic hinge value of the rolled section. As for rigidity, all of the connections were ~~rigid~~ adequate except the Type 2 and 8B which in the elastic part and early elasto-plastic part showed higher rotations. These extra rotations may increase the deflections in the frame about 5 to 10 percent.

emphasize that this is in the knee, not at rolled section

I don't check this values.

However, some of the connections fail relatively suddenly, as soon as they reach their maximum load. They fail to carry the maximum moment through large rotations. Such connections are ~~Connection~~ B, C, G and H, and they may be regarded as unsatisfactory.

I don't agree with this. It is o.k. for plastic design concept that they are unsatisfactory.

(D) These curves give the moment at the knee. If, on the other hand, the moment at the end of the rolled section or the beginning of the knee is plotted against rotations, we obtain the curves shown in Figure 52. It is obvious that Connection B has not developed the M_p value of the 8B13 section at the beginning of the knee. The other three connections have developed the plastic hinge, although their behavior is different, as you see.

The place where the plastic hinge (or equivalent moment) should develop depends on the ~~design~~ requirement laid down by the designer. If the designer wants the M_p value to be developed at the knee ~~all~~ connections A to N ~~is~~ are satisfactory, P is not. On the other hand, if the designer, in order to achieve ~~further~~ economy, wants the plastic hinge value to be developed at the end of the rolled section, some of the connections are unsatisfactory, ~~it~~ namely, ——————

beam of ~~rolled~~ section

Table VII VIII? summarizes the test results. The end column shows that if the second criterion of strength is used, Connections B, C, I, J, N and P are decidedly unsatisfactory under different moment diagram (longer legs).

I would avoid use of a table

An interesting subject to discuss shortly briefly is the mode of failure of the various connections. Figure 71 shows the local buckling in the compression flanges

(D) Should a slide be inserted here to lead the listener to the other concept? Perhaps you could sketch on the board.

of the Connection P. However, this connection failed because of:

a. Extensive shear yield

b. Local buckling after extensive yieldings

c. Crack

The crack which developed is shown in Figure 72.

leave out.

Figure 79 is a typical example of how the connections A to N failed.

A is better than 79. Can't see the local buckling, but I see the value of 79 for yield pattern.

You see the extensive yield that took place in the knee and outside the knee. Yielding occurred both in the tension and compression zones. The connection failed finally due to ~~however by~~ local buckling yielding of the compression flanges which you see in this picture. (describe) (assume good lateral support) At first the local buckling is symmetrical. Later on, as the deformations increase, one side of the flange deflects more than the other, thus bringing about the buckling of the web and the failure of the connections.

How about lateral buckling?

Figure 87 shows Connection B at the end of the test. Note the yield pattern and the local buckling in form of waves in the compression flanges of the built-up knee.

Lateral forces were measured with SR-4 gages mounted on the lateral supports (bars). These forces were found to be a ~~very~~ small fraction of the total force on the connection. Figure 78 shows the local buckling curve and the lateral force. Note that local buckling occurs more or less simultaneously with lateral buckling. This is the case not only in this connection but in all other connections in which the local buckling and lateral deflections were measured.

Figure 88 shows the permanent distortion in Connection B because of lateral buckling. Figure 96 is another example of permanent distortion due to lateral buckling. Note the bars used for lateral support and the SR-4 gages on them. Also note the level bar supports.

OK

No! This is not a good photo

Frankly, I don't think much of the design recommendations — probably because I've not been able to find the basis upon which they were made. Why not summarize the results?

The following are some design recommendations:

A. Square Knees

1. Use a diagonal stiffener, as in Type 2 or 8B.
2. The thickness of diagonal stiffeners should be:
    a. About twice the thickness of the thinner flanges of the two rolled sections.
    b. About the same thickness as the thinnest of the flanges for knees similar to Connection L&M, Type 8B.

B. Bracketed or Haunched Knees

1. The slope of the haunch must be such that when the ultimate is reached the moments in various sections of the haunch are equal or smaller than the M_y, the initial moment yield for the sections.
2. The M_y's for ordinary slopes at the haunch may be calculated with the ordinary theory.
3. Use stiffeners at points of internal thrust.
4. In bracketed knees the depth of the bracket should be equal to the depth of the section to which it is connected.
5. Use stiffeners to distribute direct forces such as external loads or internal thrusts and to support the web against buckling.
6. The stiffeners must be in general of the same thickness as the web.
7. The length L of the stiffener, which should be enough to transfer the thrust to the web, may be obtained from the relation

$$L = \frac{tsb}{w}$$

where: b = width of the rolled section flange.
w = web thickness of the rolled section.

1. ~~Importance of diag~~. See A1 above.
2. Suggest adequate thickness of web if diagonal is objectionable — further tests suggested.
3. Influence of stiff in 8B is negligible (?) recommend type L?
4.