AD 293
Web panel Zones in Vierendeel Girders (Part 1)

Recently our advisory desk has received a number of questions about Vierendeel girders and particularly about the application of clause 6.1.9 in BS 5950-1: 2000 to joint design. A typical Vierendeel joint between two I-section members is illustrated in Figure 1. The majority of the questions have related to the distinction between F_v and F_{vp} as described in clause 6.1.9 in regard to this type of joint. Clause 6.1.9 defines F_{vp} but leaves the shear force, F_v, which the web panel zone must resist, to be determined by the design engineer. This AD provides advice on the distinction between these two values and AD294 will provide advice on the design of the web panel zone. As a result of the end moments in the vertical members, the magnitude of the shear force in the web panel zone (F_v) in the chord member for this type of joint might be several times that of the shear force in the chord outside the web panel zone.

Background

A Vierendeel girder or truss is an open web girder consisting of top and bottom chords with vertical internal and end members joined by moment resisting connections. A typical girder is illustrated in Figure 2. The members of a Vierendeel girder are therefore subject to bending (Vierendeel moments), shear and axial load effects.

Although Vierendeel girders are more expensive to produce than conventional trusses with diagonal members, they provide useful solutions in certain scenarios; for example, for storey-deep transfer structures when the removal of the diagonal members from a conventional truss is desirable for access reasons.

Structural Analysis

Vierendeel girders are usually designed elastically and the model used in the structural analysis of these girders normally consists of a series of line elements connected to moment resisting (rigid) nodes. Plastic design is used occasionally.

Typical results for an elastic structural analysis of a Vierendeel girder are shown in Figure 3. The members of the girder are then checked for the interaction of moment, shear and axial load using a design code, typically section 4.8 in BS 5950-1: 2000

Vierendeel girders lend themselves to analysis by statically determinate sub-frames due to the presence of points of inflection in the middle region of the members. Typical results for the structural analysis of a simple sub-frame are shown in Figure 4.

Analysis of Joints

Designers should be aware that structural analysis based on line elements alone will not in itself be sufficient to provide the design value of the shear force in the web panel zone for the typical joint shown in Figure 1. The depths of the internal members and chords must be taken into account to find the value of the shear force in the web panel zone.

The calculation of the shear force in many web panel zones may be carried out by a few simple calculations but the subject is best introduced by an understanding of the interaction of member sizes and sub-frames. Figure 4 shows the forces and moments on a sub-frame of the upper part of the left side of the Vierendeel girder shown in Figure 2 and subject to vertical loads.

If the moments and axial force in the vertical

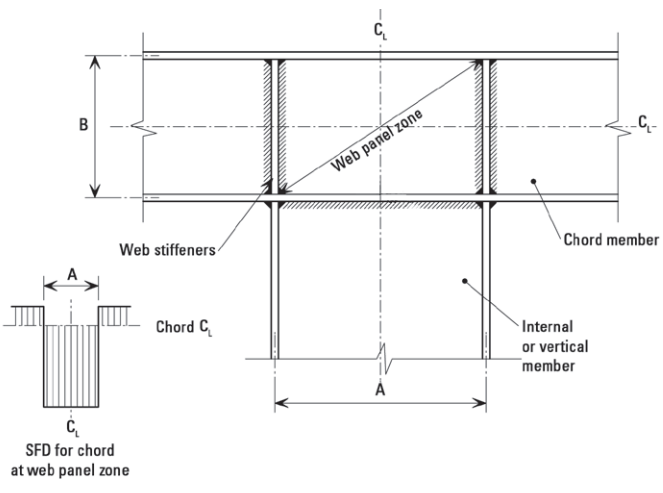

Figure 1. Typical Vierendeel Joint using Open Sections

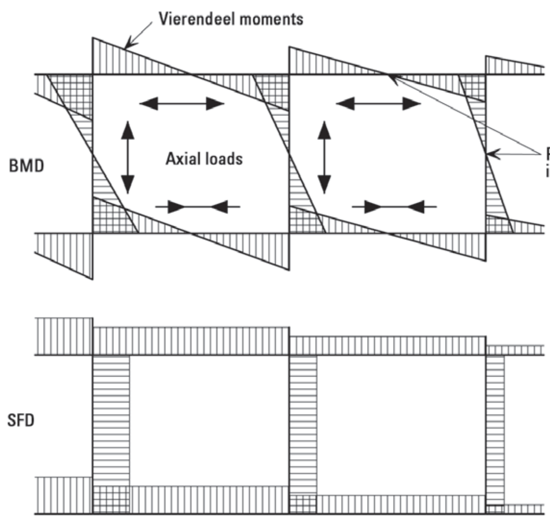

Figure 3. Elastic Bending Moment and Shear Force Diagrams for a Vierendeel Girder

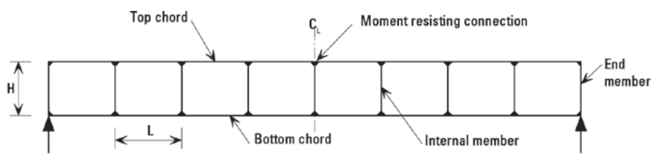

Figure 2. Components of a Vierendeel Girder

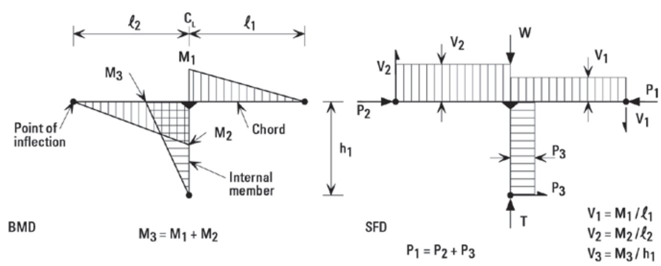

Figure 4. Bending Moment and Shear Force Diagrams for simple Vierendeel sub-frame

member are assumed to be carried by the flanges alone then the bending moment and shear force diagrams for the chord are simple linear diagrams as shown in Figure 5.

In terms of clause 6.1.9 of BS 5950-1: 2000, F_{vp} is the panel zone shear force resulting from the introduction of the global end moment from the vertical member, where the flanges are a distance A apart, and is given by:

$$F_{vp} = M_3/A = (M_1 + M_2)/A$$

This model is the same as used in BS 5950-1: 2000 clause 6.1.9 in which:

$$F_{vp} = M_{tra} /(D_d - T_b) = M_3/A$$

However, the actual shear force in the web panel zone is the value F_v as shown in Figure 5. The value of Fv depends on the shear in the chord, the load on top of the chord and the compressive force in the vertical member and is given by:

$$F_v = F_{vp} – V_1 – W/2 + T/2$$

This is usually taken as:

$F_v = F_{vp} – V_{min}$ where V_{min} is the lesser of V_1 and V_2

As the bending moment diagram is linear in this analysis and shear is the rate of change of moment (or in other words, the slope of the bending moment diagram), the shear force in the web panel zone may alternatively be determined from:

$$F_v = (M_{1f} + M_{2f}) / A$$

Where the values M_{1f} and M_{2f} are determined from the global forces in the sub frame and the width of the vertical member. If the full cross–section of the vertical member is required to resist the moment, a more complex analysis needs to be performed, which will give curved bending moment and shear force diagrams in the connection zone.

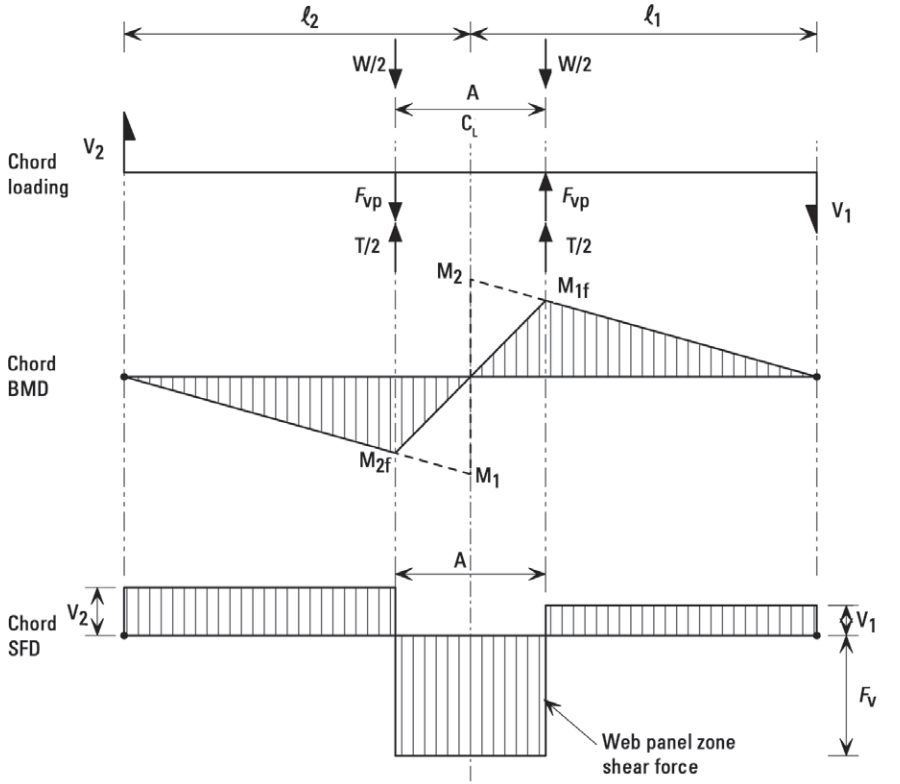

Figure 5. Modified BMD and SFD for Chord of Vierendeel Girder

AD 294 will conclude this series of notes on Vierendeel Girders in NSC Vol 14 No 1 January 2006.

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