Investigation of frame with semi-rigid joint

Investigation of Frame with Semi-Rigid Joint

Essais de cadres à joints semi-rigides

Untersuchung von Rahmen mit halbsteifen Knoten

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SUMMARY

The effect of joint flexibility on the static and dynamic behaviour of moment resisting frames is being studied analytically and experimentally. A thirty three storey steel frame is analysed to demonstrate the effect of the joint flexibility on the horizontal deflections and the natural frequencies of vibration of the frame. Two near full scale frames are being tested. The behaviour of the joints and the frame are monitored concurrently. The analytical results and the testing program are briefly explained here and together with the experimental results are being illustrated on the poster in more detail.

DESCRIPTION OF WORK

Flexibility of joints has a significant effect on the behaviour of structural frameworks especially in high rise construction. It magnifies the lateral deflections which directly affect the serviceability of buildings and influence the stability of structures through the second order effects. Flexibility of joints also alters the dynamic characteristics of structures in terms of their natural frequencies, mode shapes and damping characteristics.

The results of a comparison made on a thirty three storey moment resisting frame made of steel is given in Table 1 and Figure 1. The frame consists of typical 3 x 8 m span x 3.6 m high storeys and has a contributary breath of 5 m perpendicular to the wind direction. The beams and columns are selected from rolled Universal Beams and Universal Columns respectively. The standard end plated connection with eight high strength bolts is used typically [1]. The frame was designed for a sway limit of 0.002 of the height when full rigidity was assumed for all connections.

The wind loading is determined based on the gust factor method of the Australian loading code [2] for a wind velocity of 41 m/s in a suburban terrain. The frame is loaded and analysed for three different conditions:

1. All joints are fully rigid.
2. All internal joints are rigid and all external joints are semi-rigid.
3. All joints are semi-rigid.

A small deflection elastic analysis is used. The semi-rigid joints are modelled as linear torsional springs at the beam ends. The springs stiffnesses were calculated as the secant stiffnesses of the joints using Yee and Melchers analytical model [3].

	Condition 1	Condition 2	Condition 3
First Natural Frequency (Hz)	0.185	0.173	0.141
Second Natural Frequency (Hz)	0.511	0.472	0.379
Percent of Critical Damping	2	3.5	5
Gust Factor, G	2.61	2.55	2.55
Wind Pressure at top of the Building (KPa)	1.44	1.40	1.40
Total Lateral Load (KN)	622	608	608
Top Floor Displacement (mm)	240	266	400

Table 1 Comparison of the analytical results

As shown in Table 1, the natural frequencies of the frame are marginally reduced by the flexibility of the exterior joints (less than 6% for Condition 2) The flexibility of the internal joints, however, has reduced the frequencies markedly (more than 18% for Condition 3). The effect of the joint flexibility on the gust factor, and consequently on the loading, is seen to be negligible. The horizontal displacements are affected in the same manner as the natural periods of vibration and is magnified by 67% at the top floor when the flexibilities of all connections are considered. The deflected shapes for Condition 1 and Condition 3 are shown in Figure 1. The damping for frames with Conditions 1 and 3 is assumed respectively as 2% and 5% of the critical damping as normally used in literature. For Condition 2, an intermediate value of 3.5% is assumed.

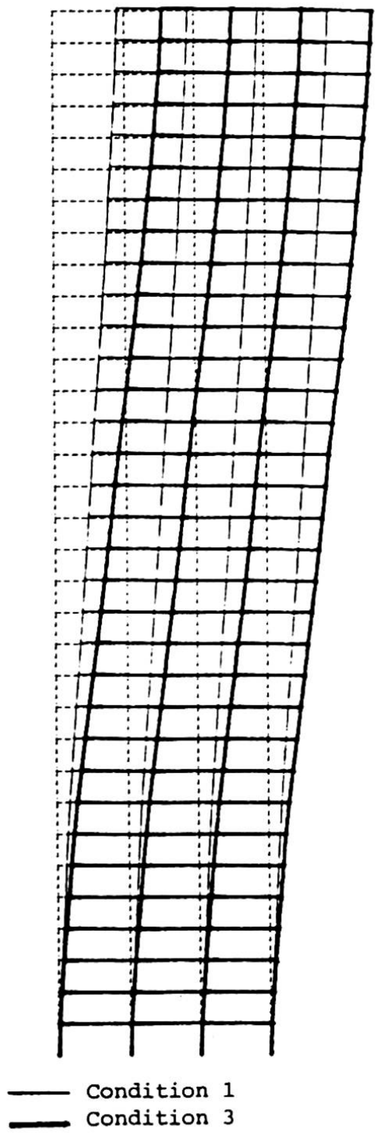

Fig. 1 Deflected Shape

To verify the above analytical procedures an experimental investigation of the frames containing semi-rigid joints is being conducted. Two near full scale single span pin based frames with standard end plated connections are tested. The geometric imperfections of the frames are fully surveyed. Non-destructive free vibration tests are performed for two different levels of amplitude and three different periods of vibration. The frames are then tested to failure statically. During these tests, the behaviour of the connections as well as the frames is monitored. The extent and spread of plastification is followed to near failure load during the static testing.

The frames are made of 150 UC 37.2 columns and 200 UB 25.4 beams. They are pin based frames with a span of 2.15 m and a height of 2.1 m approximately. The beams are fitted with 28 mm end plates, each being connected to the column with 8 M20 - 8.8 high strength bolts. Strain gauges are used to monitor the plastic zones. Four LVDT's (two on each side of the column) are employed to register the moment-rotation relationship of each joint. The joint rotation is defined as the change of the angle between the end plate of the beam and a horizontal line on the column at the level of the beam bottom flange. A LVDT and an accelerometer are used to register the horizontal response of the frame when subject to free vibration or to horizontal static leading. The experimental findings and their comparison with analytical results are illustrated on the poster.

REFERENCES

1. Aust. I.S.C., Standardised Structural Connections. 3rd Ed., 1985.

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3. YEE, Y.L. and MELCHERS, R.E., Moment-Rotation Curves for Bolted Connections, J. of Struct. Engr., ASCE, Vol. 112, No. 3, March 1986.