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16. Abstract (Limit: 200 words)

The progress of two investigations into the cyclic behavior of two structural steel bracing systems is reported. In one study the centerlines of beams, columns, and braces meet at each joint resulting in concentrically braced frames. Three one-half scale identical braced frames have been constructed, two of which were tested; the third is being prepared for the next experiment. In the first experiment an attempt to determine the static capacity of the frame was made; in the second, progressively increasing completely reversed cyclic displacements were applied; in the third test, cyclic displacements with a bias in one direction will be applied. In the eccentric bracing systems study, braces are deliberately made eccentric with respect to the intersection of the beam-column axes. There are strong indications that bracing systems with eccentric joints provide good energy dissipation characteristics. The results of experiments with symmetric K-braces in which large eccentricities were introduced at the panel centerline led to good results. Inverted Y-braces offer another possibility. In this investigation a detailed study of the eccentric bracing configuration is pursued as being particularly well suited to American construction practice. However, since the inelastic activity occurs near the beam-column connection, this design requires careful scrutiny. Common to both the concentrically braced and eccentric bracing systems studies, the development of more accurate cyclic constitutive relations for inelastic behavior of structural steel is also being pursued.

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Investigations into the cyclic behavior of two structural steel bracing systems are in progress. In one study, sponsored by the National Science Foundation, the centerlines of beams, columns, and braces meet at each joint resulting in concentrically braced frames. In the other study sponsored by the American Iron and Steel Institute, the braces are deliberately made eccentric with respect to the intersection of the beam-column axes. Common to both studies, the development of more accurate cyclic constitutive relations for inelastic behavior of structural steel is also being pursued.

Concentrically Braced Frames

Three one-half scale identical braced frames have been constructed, two of which were tested; the third is being prepared for the next experiment. The overall width of each one of these frames is 17 ft which corresponds to one half of the building width. Three stories of braced panels, one above the other, are 14 ft wide. The braces in the lower two stories form an X-brace, whereas the braces in the third floor form an inverted K-brace. The overall height of the specimens is 18 ft 8 in. The columns and beams are made of small wide-flange sections, the braces are tubular.

In the first experiment an attempt to determine the static capacity of the frame was made; in the second, progressively increasing completely reversed cyclic displacements were applied; in the third test, cyclic displacements with a bias in one direction will be applied. During the experiments a hydraulically actuated gravity load simulator applies the required vertical forces. A horizontal hydraulic jack at the top of the frame applies the lateral loading in a quasi-static manner.

Characteristic of concentrically braced frames, their inelastic behavior during the application of large lateral loads is strongly influenced by the inelastic behavior of the individual braces. This strong influence is felt because the brace contributes the most to the lateral stiffness, and therefore, usually yields or buckles before the remainder of the structure. Several tests to determine the cyclic behavior of braces of the type used in the test frames are in preparation. A few experiments on full size braces are also a part of the program.

As an aid to the analytical prediction of the behavior of individual braces, experimental and analytical studies are in progress on the refinement of constitutive relations for cyclic plasticity. For this purpose tubular specimens of steel having approximately the same

properties as that of rolled sections have been made. Some of these are being tested cyclically in the MTS tension-compression machine; the others, will be subjected to cyclic torsion. Some progress has been achieved in analytically describing this behavior [1]. Computer programs for material and geometric nonlinearities, which with some modifications may be applicable for this study, have been developed earlier [2].

Eccentric Bracing Systems

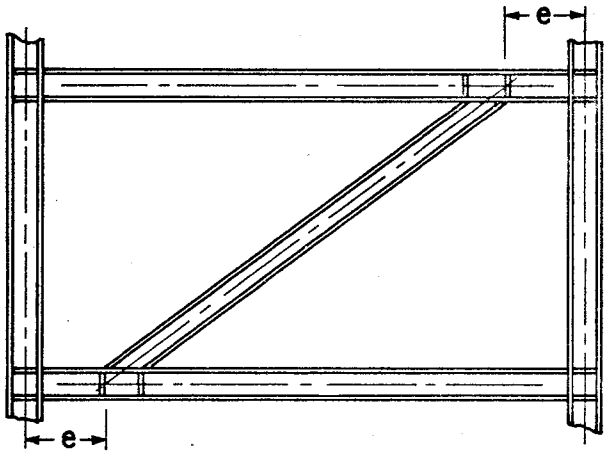

Fig. 1

There are strong indications that bracing systems with eccentric joints provide good energy dissipation characteristics. The results of experiments with symmetric K-braces in which large eccentricities were introduced at the panel centerline led to good results [3]. Inverted Y-braces offer another possibility [4]. In this investigation a detailed study of the eccentric bracing configuration shown in Fig. 1 is pursued as being of a type particularly well suited to American construction practice. However, since the inelastic activity occurs near the beam-column connection, this design requires careful scrutiny. No data on experimental investigations on this type of connection are available.

The bracing system selected for the study appears to offer excellent characteristics: it assures the frame of a high degree of stiffness, while at extreme loadings the energy is dissipated in the beams thereby obviating the undesirable buckling effects of the braces. The studies to-date show that the lateral stiffness of the frame is not significantly reduced from that of concentrically braced frames for moderately high values of eccentricity. It also appears that there may be an overall saving in the weight of steel. Although the braces, which are designed to prevent buckling, will be heavier, the columns will be lighter because of better control of the load transfer to the column. Moreover, an eccentrically braced frame is more highly redundant thereby tending to develop more regions of inelastic action for absorbing and dissipating energy.

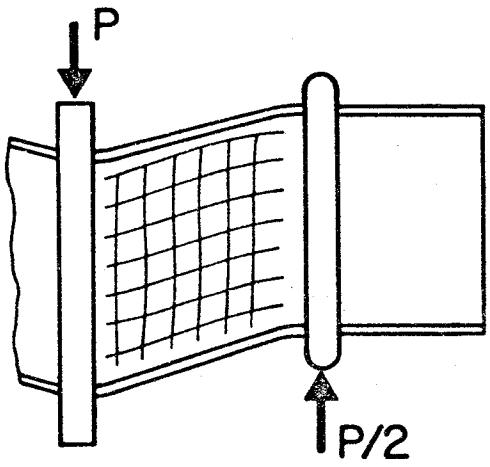

Fig. 2

The stresses in the eccentric zone are characterized by very high shear stresses in the web. Since the only tests of shear yield of the web reported

in the literature [5] are monotonic tests, a series of simply supported beams in shear are being tested under cyclic loads. These specimens are designed to simulate one half of the eccentric zone. A schematic outline of a photograph of one of these specimens severely distorted in shear is shown in Fig. 2. Note the grid for photogrammetric measurements. The behavior of such members is very different from those in flexure. These experiments should provide information for the development of a simple analytical model for shear yield of beams, and show the effects of web buckling and diagonal tension formation on the hysteretic loops. It is also intended to study the nonlinear cyclic behavior of these eccentrically connected joints using finite elements, see Fig. 3. The design and tests of two one third-scale model steel frames with eccentric braces will follow to complete this program.

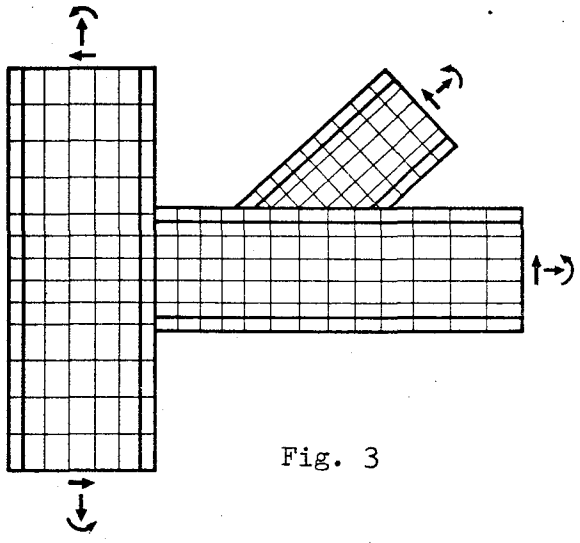

Fig. 3

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