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Acceptance Criteria for Moment Frames Based on Structural Testing (T1.1-01) and Commentary (T1.1R-01)

An ACI Standard

Reported by ACI Innovation Task Group 1 and Collaborators

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Acceptance Criteria for Moment Frames Based on Structural Testing and Commentary

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Commentary on Acceptance Criteria for Moment Frames Based on Structural Testing

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R1.0—Notation

Only symbols used in this Commentary that are additional to those in Appendix E of ACI 318-99 and Standard T1.1-01 are defined in the following:

A_h = area of hysteresis loop
E_1, E_2 = peak lateral resistance for positive, negative, loading for third cycle of loading sequence
f_1 = factor on live load defined in R2.6
h = height of column of test module, in. or mm
K,K' = initial stiffness for positive, negative, loading for first cycle
θ_1,θ_2 = drift ratios at peak lateral resistance for positive, negative, loading for third cycle of loading sequence
θ_1',θ_2' = drift ratios for zero lateral load for unloading at stiffnesses K,K' from peak positive, negative, lateral resistance for third cycle of loading sequence (Fig. R2.4)
Δ = lateral displacement, in. or mm. See Fig. R2.1
Δ_a = allowable story drift, in. or mm. See Table 1617.3 of IBC 2000

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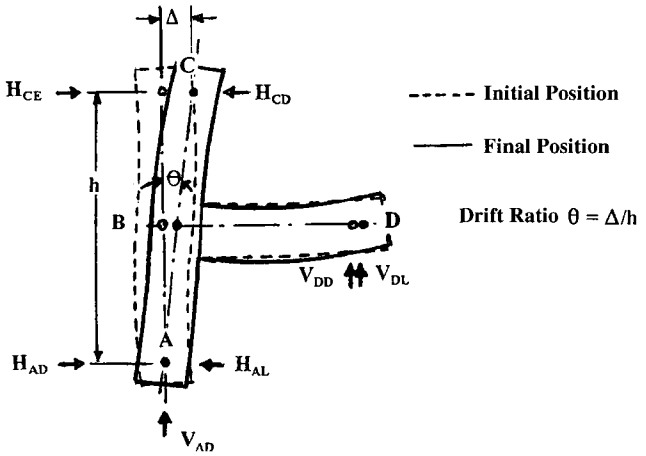

Fig. R2.1—Deformations of exterior column-beam test module.

R2.0—Definitions

R2.1—Where a column exists on both sides of the joint, its chord is defined by the line joining the loading (or support) points. The same is true for a beam that exists on both sides of the joint. If a column or beam exist on one side of the joint only, then the chord is defined by the line joining the end loading (or support) point and the joint centerline.

The drift ratio θ concept is illustrated in Fig. R2.1 for an exterior column-beam module. The position of the module at the start of testing, with its self-weight only acting, is indicated by broken lines. The module is pin supported at *A* and roller supported at *D*. The self weight is taken by vertical reactions V_{AD} and V_{DD}. That weight, however, also causes a twisting about the centroid *B* of the joint so that opposing horizontal reactions, H_{AD} and H_{CD}, develop. Under self weight alone, the pin at *C* must be constrained to lie on the centroidal axis of the column that passes from *C* through *B* to *A*. That chord is the vertical reference line for drift measurements. The setup also constrains the chord joining the centroid of the joint *B* and the centroid of the section at *D* to be horizontal.

For acceptance testing, a lateral force H_{CE} is applied to the column through the pin at *C* and results in the specimen taking up the deformed shape indicated by solid lines. The lateral force causes reactions H_{AL} at *A* and V_{DL} at *D*. The column at C displaces laterally by an amount Δ. The chord defining the reference axis for the beam, however, remains horizontal. The drift ratio is the angular rotation of the column chord with respect to the beam chord and for the setup shown equals Δ/h where *h* is the column height and equal to the distance between the pin at *A* and that at *C*.

R2.3—The column overstrength factor λ should be selected so that λE_n is greater than the probable lateral resistance E_{pr}. It is to be expected that the maximum lateral resistance of the test module E_{max} should be similar to E_{pr}. In 21.4.2.2 of ACI 318-99 the ratio of the sum of the moments at the faces of the joint, corresponding to the nominal flexural strengths of the columns framing into that joint, to the sum of the moments at the faces of the joint, corresponding to the nominal flexural strengths of the beams framing into that same joint, must exceed 1.2. Further, in T-beam construction, where the slab is under tension under moments at the face of the joint, slab reinforcement within an effective width defined in 8.10 of ACI 318-99 must be assumed to contribute to the flexural strength if the slab reinforcement is developed at the critical section for flexure. Hence the λ specified here is a comparable quantity to, but is not the same quantity as, the 1.2 value specified in ACI 318-99. For application of this Standard, the column overstrength factor is to be specified in the design procedure and, when the contribution of the reinforcement in the slab is considered, the requirement of 21.4.2.2 must be met. There is, however, no requirement to provide a slab on the test module.

Moment strengths should take into account simultaneous application of axial force and direction of loading. The axial forces on the beam and the column should be those causing the largest and the smallest moment strength possible, respectively. Most beams, however, will have zero axial force and for most columns the smallest strength will also be for zero axial force. Directional effects require that the sign of any column axial force and beam bending moments be consistent. For example, for an end joint, column tension effects need only be considered in combination with beam positive moment strength.

Where prestressing steel is used in frame members the stress f_{ps} in the reinforcement at nominal and probable lateral resistance shall be calculated in accordance with 18.7 of ACI 318-99.

R2.4—The relative energy dissipation ratio concept is illustrated in Fig. R2.4 for the third cycle to the drift ratio of 0.035. For Fig. R2.4, it is assumed that the test module has exhibited different initial stiffnesses, *K* and *K′*, for positive and negative lateral forces and that the peak lateral resistances for the third cycle for the positive and negative loading directions, E_1 and E_2, also differ. The area of the hysteresis loop for the third cycle, A_h, is hatched. The circumscribing figure consists of two parallelograms, *ABCD* and *DFGA*. The slopes of the lines *AB* and *DC* are the same as the initial stiffness *K* for positive loading, and the slopes of the lines *DF* and *GA* are the same as the initial stiffness *K′* for negative loading. The relative energy dissipation ratio concept is similar to the equivalent viscous damping concept used in 13.3.3.1 and 13.9.5.2 of the 1997 NEHRP Provisions and Commentary[1] for design and evaluation of seismically isolated structures.

For a given cycle, the relative energy dissipation ratio β is the area A_h inside the lateral force-drift ratio loop for the module divided by the area of the effective circumscribing parallelograms *ABCD* and *DFGA*. The areas of the parallelograms equal the sum of the absolute values of the lateral force strengths, E_1 and E_2, at the drift ratios θ_1 and θ_2 multiplied by the sum of the absolute values for the drifts ratios θ_1' and θ_2'.

R2.6—The required gravity load is the value given by the governing building code. Since the purpose of this document is to define acceptance criteria for weak-beam/strong column moment frames not satisfying the requirements of Chapter 21 of ACI 318-99, the response of the beam will generally control

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