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Sensitivity of Incremental Dynamic Analysis Results on Selected Constitutive Materials

Abstract

Incremental Dynamic Analysis (IDA) is a dynamic procedure for determination of lateral capacity based on scaled time histories of earthquakes and provides more reliable results than non-linear static procedures (e.g., pushover analysis). Varies uncertainties exist in the IDA, leading to variability in the predicted responses. Modeling uncertainty with regards to the adopted nonlinear materials modeling is an important one. In this work, different nonlinear constitutive material models for concrete and reinforcing steel are investigates the sensitivity of IDA results to the different constitutive models is determined.

Incremental Dynamic Analysis

The development of IDA has been credited to the growth in computer processing capabilities which allowed complexities to be handled in analysis methods. Figure 1 shows a flowchart of the IDA procedure. The maximum values of base shear and roof displacement recorded during a particular scaled non-linear time history analyses corresponds to a single point in the IDA curve. Variation of scale factors for a single time history record yields multiple points creating a single IDA curve. The curve provides an indication of the relationship between seismic capacity and demand.

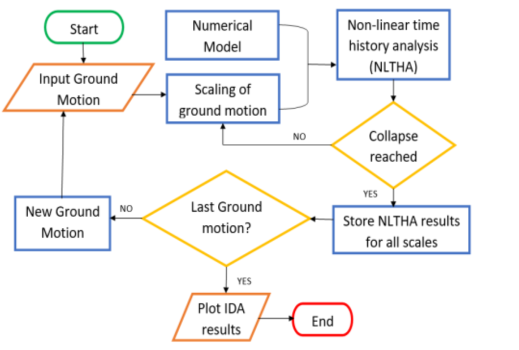

Figure 1. Flowchart showing the process of incremental dynamic analysis

Constitutive Material Models

A set of constitutive material models are selected (Table 1) and then validated against experimental tests of reinforced concrete columns subjected to cyclic, lateral loading. Fibre-based distributed plas-ticity model is used in OpenSees, an opensource structural analysis frame-work.

Figure 2 shows the experimental setup for a single column under compression and cyclic loading and Figure 3 a sample comparison between numerical analysis and experimental result.

Table 1: Considered Constititive material models

Material	Author/s	Distinct feature/s
Concrete02	Yassin (1994)	Linear tension softening; confinement branch only by scaling
Concrete04	Popovics (1973)	Non-linear tension softening
Concrete07	Chang & Mander (1994)	Empirical relations for unloading & reloading; confinement branches
Steel02	Menegotto-Pinto (1973)	Isotropic strain hardening
SteelMPF	Filippou et al. (1983)	Extended Menegotto-Pinto model
Steel4	Menegotto-Pinto (1973)	Combined kinematic and isotropic strain hardening
Reinforcing-Steel	Chang and Mander (1994) Menegotto-Pinto (1973)	Buckling and fatigue

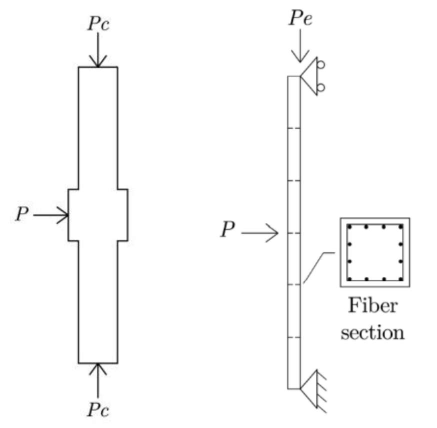

Figure 2. Considered Column and distributed plasticity model according to experiment by Douglas, 1979

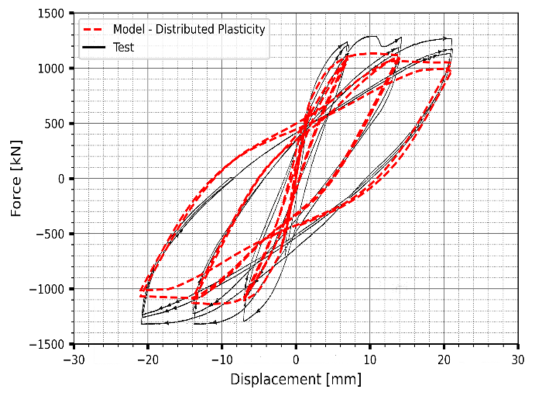

Figure 3. Experimental versus numerical cyclic static analysis results using "Concrete04" and "Steel02" model on a RC column (by Douglas)

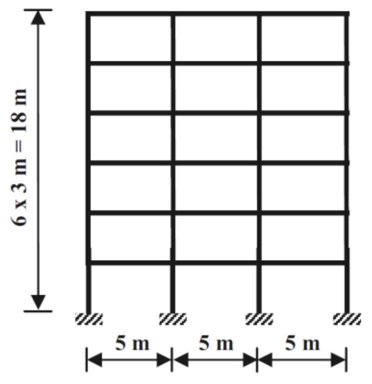

Figure 4. Considered bare frame

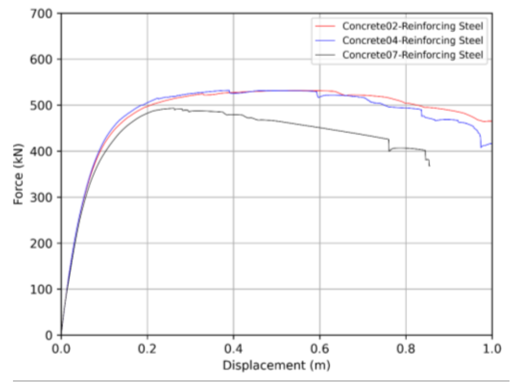

Figure 5. Pushover Analysis of the frame using material "Reinforcing Steel" and different concrete models

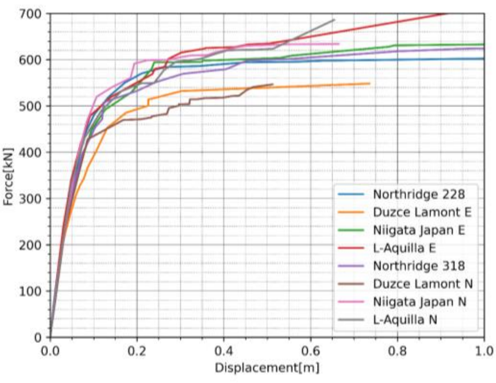

Figure 6. IDA results for the considered frame using "Concrete02" and "Steel4"

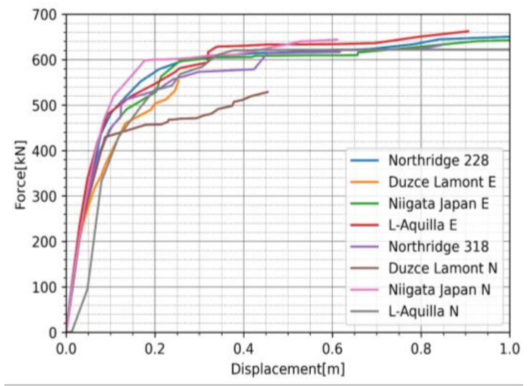

Figure 7. IDA results for the considered frame using "Concrete02" and "Reinforcing Steel"

Conclusion

It is observed for a sample case study (figure 4) that the IDA results are influenced to some extent by the material model and the selected ground motion (figures 6 and 7). On the other hand, the pushover results are impacted only by the material models (Figure 5). The IDA results varied in terms of peak strength and/or post-yielding behavior in different constitutive material models. IDA is rather time consuming and highly demanding analysis; therefore, it should be adopted only when high accuracy is required, and the structure considered has high level of importance. The IDA results differ with time histories even for the same combination of constitutive material models. Thus, a probabilistic approach would better describe the results obtained from IDA than a deterministic approach.

References

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