EXAMINATION OF SELECTED RECENT GROUND MOTION RECORDS FROM TURKEY IN TERMS OF DISPLACEMENT DESIGN PROCEDURES

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ABSTRACT

Selected near source records obtained from the 17 August and 12 November 1999 events in Turkey are studied. The records are corrected using different schemes for their effect on displacement based design tools. One of these correction procedures is thought to be suitable for the near source ground motion characteristics. The results indicate that even significant differences in the displacement traces would not be vital for the dynamic analysis of ordinary structures. However, they might be important for buildings equipped by dampers. The consistency of the effective damping concept for modifying the elastic ADRS curves in the capacity spectrum is examined. Near source ground motions demand large drifts for a wider range of periods. This underscores the importance of displacement based design procedures. The results show that the proposed damping factors for the modification of elastic spectrum does not give reliable estimates in the non-linear range. Further research is required in this area to consider the requirements imposed by near-source ground motions.

Introduction

Turkey experienced two destructive earthquakes on the western part of North Anatolian Fault system in 1999. The first event, with M_w = 7.6, occurred on August 17 and ruptured the fault approximately 140 km, and affected the İzmit Bay together with the surrounding region. The second, M_w = 7.2 event was on November 12 and extended the rupture about 30 km further towards east. Five near source ground motion records were obtained from these two earthquakes. It is believed that they will play an important role in shedding light to the challenging aspects of near field earthquakes (NFEQs). This paper works at two issues of NFEQs by using the near source records obtained from Düzce and Sakarya (Adapazarı) stations of these earthquakes.

The first issue is the influence of ground motion data processing schemes on the structural damage potential of near source earthquakes. It is understood from the Landers, Northridge and Kobe earthquakes that one of the distinct features of NFEQs is their rich long period components represented by a fling in velocity and displacement traces. The consequent large drift demand makes NFEQs more perilous for structural systems. Therefore, a well-

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established data correction procedure accounting the physical features of NFEQs should be applied to such ground motions to preserve this long period information. Conventional filtering procedures are suspected to filter out this long period information. The influence of these correction procedures on the potential damage of intermediate period regular structures is still not clear in terms of near field effects. To this end, two data correction procedures have been used to process the records at hand. One of them is called the “Standard Correction Method” (SCM) that uses the digital filtering techniques for data correction (Trifunac and Lee, 1973). The other is an alternative correction method (ACM) that considers the inherent nature of near source excitations (Iwan and Chen, 1994).

The second item treated in this paper is the consistency of effective damping (β_{eff}) concept in nonlinear displacement spectra. β_{eff} is used to modify the elastic spectral quantities into equivalent nonlinear variables for use in the Capacity Spectrum Method (ATC 40, 1996). The method compares the structural capacity with the ground motion demand. The matching is done when capacity and demand have the same displacement ductility (μ). The capacity of the structure is calculated via pushover analysis and the ground motion demand is evaluated from spectral analysis (Freeman, 1998). In this respect, the reduction of elastic response quantities into nonlinear counter pairs becomes important since structures surpass their elastic limits when subjected to strong excitations. As the deformation shift is more pronounced than the strength shift for nonlinear behavior β_{eff} is more critical for predicting the nonlinear spectral displacement. As a corollary this issue is more important for NFEQs due to their large drift demands for a wider range of periods. For this purpose, the constant ductility displacement spectra of the records under consideration will be compared with their equivalent counterparts derived from the recommended ATC 40 formulations. The results are presented in the following sections.

Near Source Records Corrected by Different Data Processing Schemes and their Affect on Structural Damage Calculations

Two data correction procedures are used for comparison purposes. The SCM corrects instrument frequency response and removes baseline shifts in the record by means of low- and high-pass filtering (Trifunac and Lee, 1973). Following the hardware improvements in data acquisition and computer systems, the procedure has gone through several refinements but the original principle, application of band-pass filters to the uncorrected data, has not changed. Another correction procedure (ACM) was proposed by considering the physical nature of NFEQs (Iwan and Chen, 1994). No filtering is applied to the raw data in order to preserve the low frequency content of the excitation. Instead, continuous or segmental curves are fitted to the raw velocity data to assure that the ground motion starts and ends with zero velocity. Since the non-physical trends of the ground motion have been removed from the corrected velocity trace, once integration of it yields the “true” displacement time history.

The above procedures are utilized to correct the near source records considered in this study. Both correction procedures yield nearly the same velocity traces and there is almost no difference in the acceleration time histories. The calculated displacements are shown in Fig. 1.

The differences in displacement are considerable especially for EW components where permanent offsets should occur in the direction of slip. For completeness, comparisons of peak ground acceleration (PGA), velocity (PGV) and displacement (PGD) values are presented in Table 1.

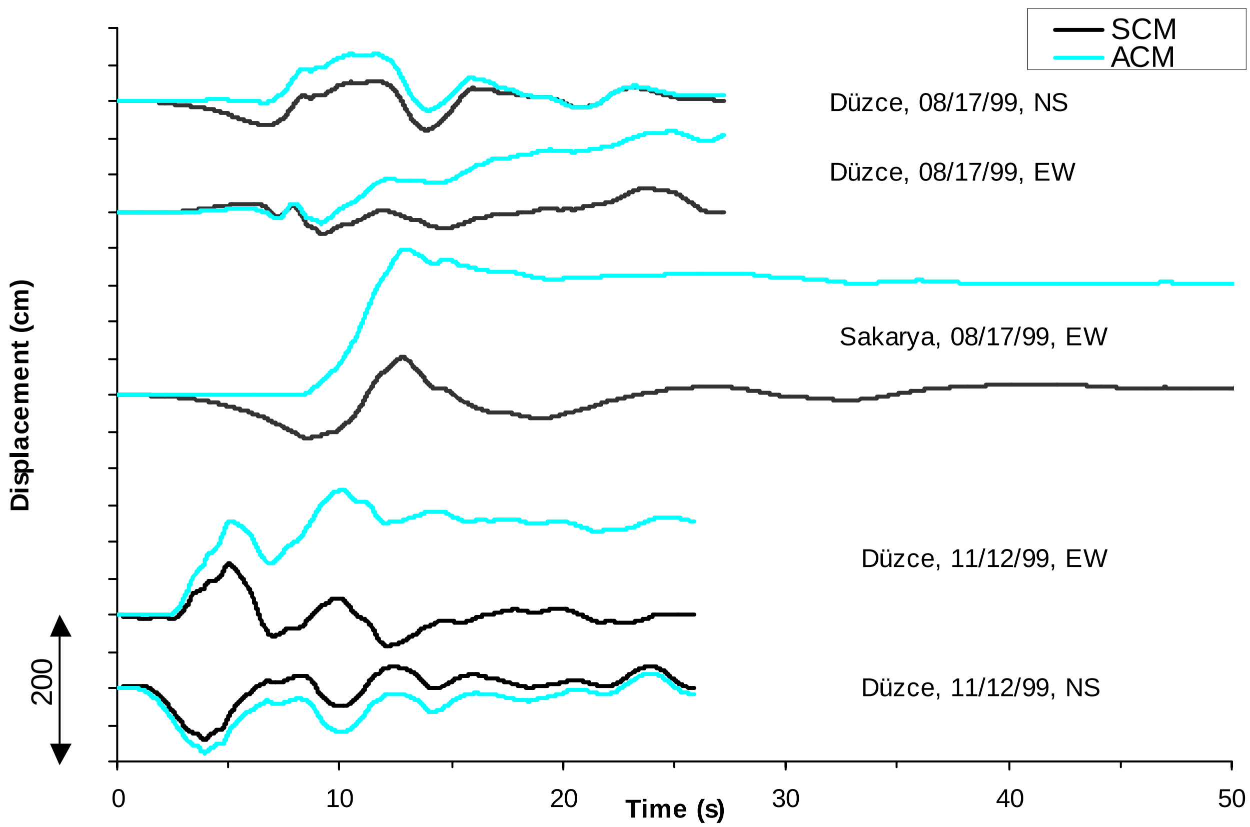

Figure1. Comparison of displacement time histories

Table 1. Comparison of maximum peak ground acceleration, velocity and displacement values

Station, Component		Distance[1] (km)	SCM PGA (cm/s^2)	SCM PGV (cm/s)	SCM PGD (cm)	ACM PGA (cm/s^2)	ACM PGV (cm/s)	ACM PGD (cm)
08/17, Düzce[2]	EW	17.1	356.52	58.56	31.45	375.55	49.61	108.57
	NS		305.82	56.49	39.51	330.51	60.59	63.81
08/17, Sakarya[3]	EW	11.6	396.93	58.90	58.90	399.37	79.80	198.64
11/12, Düzce[2]	EW	8.2	509.48	88.01	69.15	503.32	86.05	170.12
	NS		399.02	69.42	70.21	401.77	65.76	88.04

(1) Closest distance to surface rupture
(2) Site classification is soil
(3) Site classification is rock

The influence of the differences observed in the correction methods on three commonly used structural damage potential calculations are shown in Figs. 2, 3 and 4.

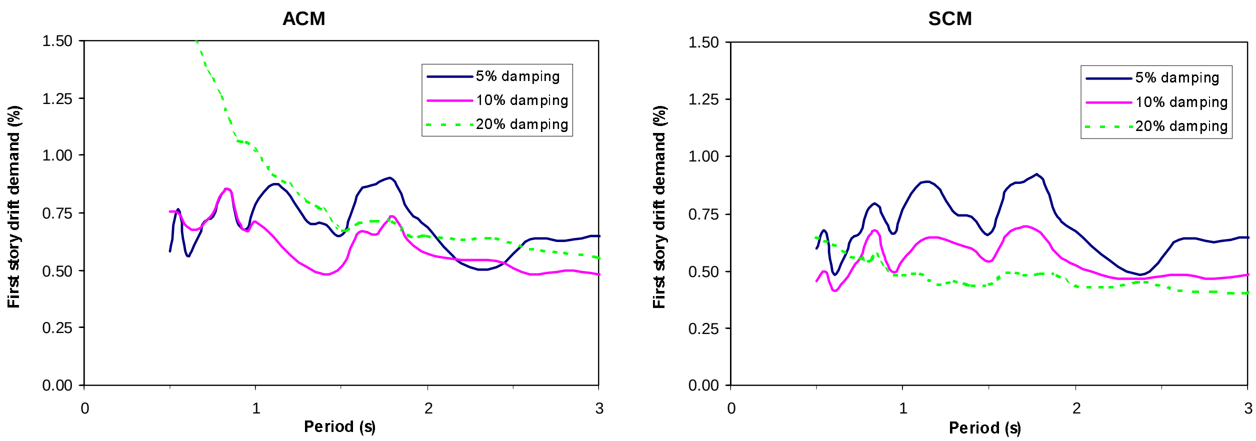

Figure 2. Linear drift spectra for the Sakarya (EW) August 17 record

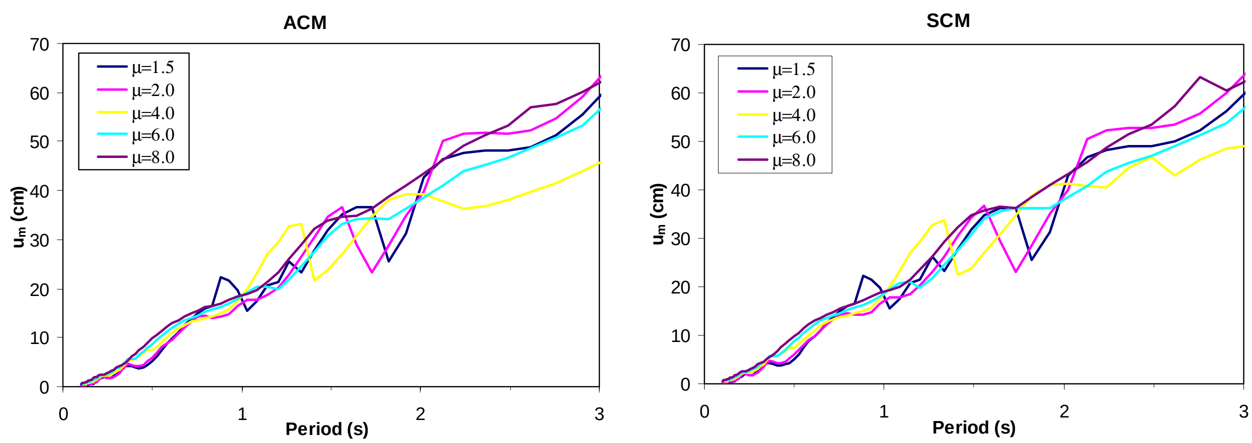

Figure 3. Inelastic displacement spectra for the Düzce (EW) November 12 record

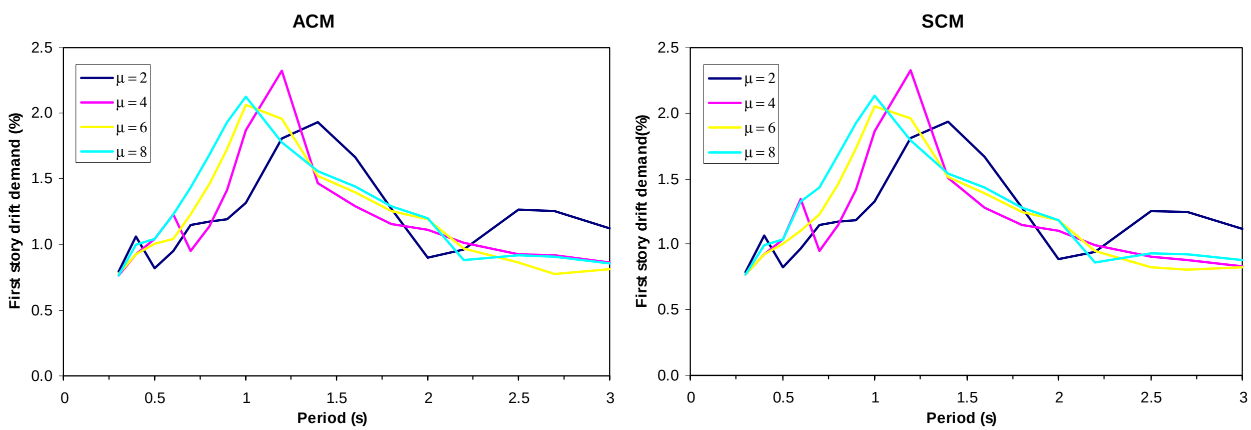

Figure 4. Inelastic drift spectra for the Düzce (EW) August 17 record

Figure 2 is drawn using the elastic drift spectrum formulation (Iwan, 1997). The curves indicate that as damping increases, the drift spectrum values calculated through ACM traces are higher. This observation would suggest that structures equipped with dampers might be very sensitive to high ground displacement values. If the ground displacement is underestimated, the calculated deformation demand for that particular earthquake would mislead the design engineer. The deformation demand is larger for NFEQs so this issue must be considered more carefully. Figs. 3 and 4 consider inelastic behavior. Fig. 3 is for single-degree-of-freedom sytems. Fig.4 is calculated by using multi-degree-of-freedom shear building model for various periods. Both figures assume a bilinear force deformation curve with a 10 percent elastic stiffness for post yielding. They also assume a 5 percent critical damping for the elastic range. The figures show that, the deformation demand is not sensitive to correction procedure. As indicated in the previous paragraphs, both ACM and SCM show similar trends in the ground velocity and ground acceleration. This suggests that for common, mid period range structures, their damage potential is mostly linked to velocity. This observation was also made in an earlier research where the differences between the displacement traces calculated via the correction methods were less significant than in this study (Akkar and Gülkan, 1999).

Modification of Elastic Spectral Displacements by the Effective Damping Concept

The damage to a structure can be controlled if deformations are limited for a specified ground shaking. This is the basic logic for displacement based design (DBD) procedures. The DBD methods are essential for NFEQs since the deformation demand of these earthquakes are more pronounced. Although CSM is not strictly a DBD procedure, the estimation of inelastic deformation demand in terms of spectral displacement quantities is one of the key steps of the method. The estimation of inelastic spectral displacements is done via effective damping (β_{eff}) concept. This concept fixes a relation between the structural damping and displacement ductility (μ). The implementation is the spectral modification factors to obtain constant ductility spectrum curves. Recent research has revealed that the CSM proposed as in ATC40 (ATC40, 1996) format has many drawbacks (Chopra and Goel, 1999). One of these shortcomings is that spectral displacements are underestimated. A typical example is given in Fig. 5 where displacement spectra of the Düzce EW record of August 17 event are compared with ATC40 curves for various μ values. Based on our research, we believe this record has a forward directivity effect that makes it more critical in terms of displacement demand. The differences between the ATC40 recommended spectra and the constant ductility curves are noted.

Conclusion

Near source records obtained from the 17 August and 12 November 1999 events in Turkey show that because the derived ground velocity from various data correction schemes exhibits a similar trend, the structural damage for ordinary intermediate period range frame systems should not change. These records show that the effective damping concept for modifying the elastic response curves does not provide reliable estimates for inelastic spectral displacement, which might be very important for determining the near source ground motion demands.

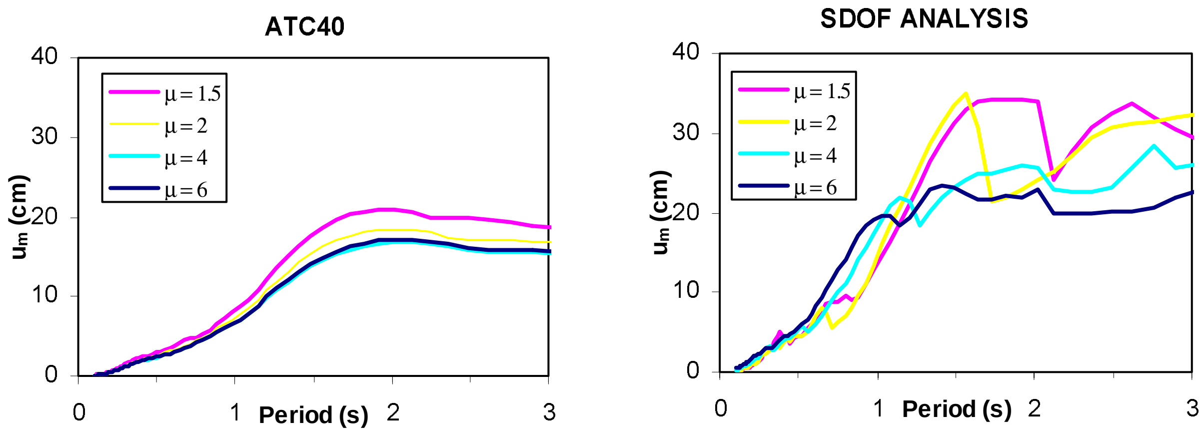

Figure 5. Düzce (EW), 17 August event

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