I－580 MASONRY BUILDING COLLAPSE SIMULATION WITH MDEM AND AN ADAPTIVE TIME STEPPING TECHNIQUE

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1. INTRODUCTION: Masonry structures are one of the most popular types of structures in many parts of the world but they are also the most frequently cause of damage and live losses under earthquake loads. Seismic analysis and strengthening of masonry building are often based on empirical measures. This may be satisfactory, in view of the complexity of the seismic response of masonry buildings but there is a necessity to use new procedures to analyze the seismic response of this type of buildings. In principle two possible approaches might be used in order to analyze these buildings: one based in experimental test and the other based on numerical modeling. This paper present an example of the second approach. We apply the Modified Distinct Element Method (MDEM) which was developed by Hakuno et al (see Meguro 1989) at the Earthquake Research Institute, The University of Tokyo. We present here also an adaptive time stepping technique in order to reduce the local time discretization error.

2. REVIEW OF EXPERIMENTAL DATA: We used the results from tests of confined masonry structures made at the Japan-Peru Center for Earthquake Engineering Research and Disaster Mitigation (CISMID) at the National University of Engineering , in Lima, Peru (Scaletti et al, 1992), to obtain the parameters for the MDEM models.

3. SIMULATION OF BEHAVIOR OF MASONRY WALLS: The MDEM is a numerical method which can follow the behavior of the media from continuous state to complete fracture. In this method, the model is composed of many circular elements (discrete elements). The Voight type model, which is composed of an elastic spring and a dashpot, is used. The effect of the material present in the pores between the granules is taken into account by an additional spring (pore spring) and a dashpot. At the initial stage, the model behaves as a continuous body, but when the forces are increased at each time step the pore springs are destroyed and the media will become discontinuous. The destruction of the pore spring show the fracture process of the structural system. The determination of the parameters was done according to the method presented in Meguro and Hakuno (1989), and using the experimental data mentioned in this paper.

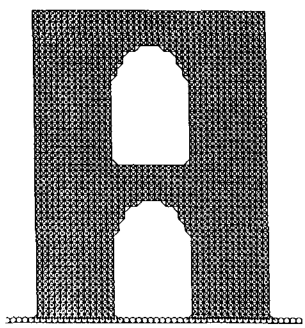

Fig. 1 Initial Distribution of pore springs. Wall with arch type openings.

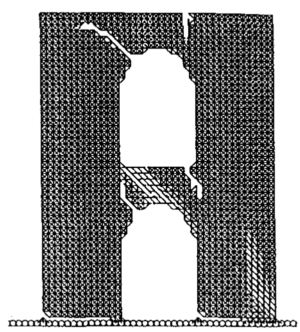

Fig. 2 Cracks at t=0.15 s. There is no significant increase in lateral strength provided by the arch.

We performed the simulation in several walls models. The model presented in Fig. 1,2 is a two story masonry wall with two arch type openings. We can observe that the arch did not provide additional horizontal strength compared with normal rectangular opening. Due to the lack of space, other models are not shown here.

4. ADAPTIVE TIME STEPPING AND ERROR ESTIMATOR: There are some situations during the MDEM simulation that the time discretization error should be controlled. A MDEM simulation can fail if the time step is not well estimated. In this paper an adaptive time stepping technique is used to control the local error. (after Zienkiewicz et al 1991).

The dynamic equation of motion is:

$$M\ddot{u}^{NM}_{n+1}+C\dot{u}^{NM}_{n+1}+Ku^{NM}_{n+1}=f_{n+1}$$

The link between successive values of t_{n+1} and t_n is established by the following truncated series:

$$u^{NM}_{n+1} = u_n + \Delta t\, \dot{u}_n + \frac{1}{2}\Delta t^2 \ddot{u}_n + \frac{1}{2}\beta_2 \Delta t^2 \Delta \ddot{u}_n$$

$$\dot{u}^{NM}_{n+1} = \dot{u}_n + \Delta t\, \ddot{u}_n + \beta_1 \Delta t\, \Delta \ddot{u}_n$$

$$\ddot{u}^{NM}_{n+1} = \ddot{u}_n + \Delta \ddot{u}_n$$

where NM means Newmark values. The parameters β_1 and β_2 are related to the accuracy and stability of the scheme. ($\beta_2 >= \beta_1 >= 1/2$). By expanding the Taylor series the exact u_{n+1} value may be estimated as:

$$u^{EX}_{n+1} = u_n + \Delta t\, \dot{u}_n + \frac{1}{2}\Delta t^2 \ddot{u}_n + \frac{1}{6}\Delta t^3 \dddot{u}_n + O(\Delta t^4)$$

After some mathematical manipulation the local error may be estimated as:

$$e = \frac{1}{2}\Delta t^2 (\beta_2 - \frac{1}{3})(\ddot{u}^{NM}_{n+1} - \ddot{u}_n)$$

The time step can be adjusted according with this value and a prescribed tolerance. The new step size Δt_{new} can be predicted as:

$$\Delta t_{new} = \sqrt[3]{\frac{\eta_t}{\eta}}\, \Delta t_{old}$$

where n_t is the prescribed tolerance and n is the error norm. We present the comparison between the new numerical integration scheme and the original one used in the MDEM code (see Fig. 3,4,5,6)

5. CONCLUSIONS: The simulation of masonry building behavior under earthquake loads shows a good agreement with previous seismic damage of this type of structures. The adaptive time stepping technique is an useful tool for MDEM simulations because the error at each time step can be evaluated and the time step adjusted accordingly.

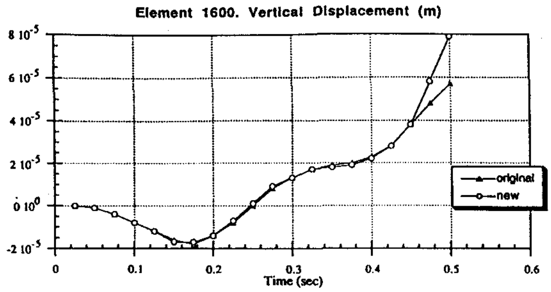

Fig. 3 Comparison between the original integration schemes of MDEM code and new adaptive time stepping. Vertical displacement at upper-right elem.

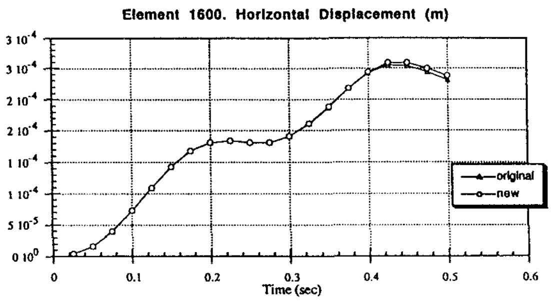

Fig. 4 Comparison between the original integration schemes of MDEM code and new adaptive time stepping. Horizontal displacement upper-right elem.

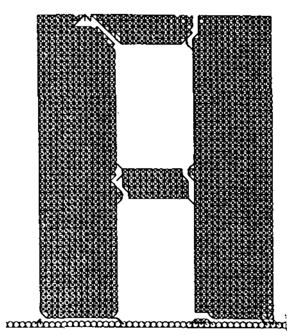

Fig. 5 Results from original MDEM code.

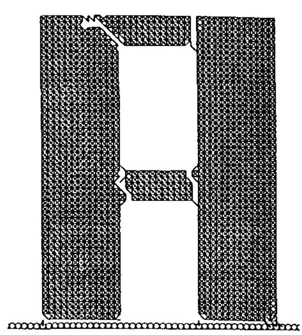

Fig 6 Results from new adaptive time stepping technique

6. REFERENCES Meguro K. and M. Hakuno. 1989. *Fracture analysis of concrete structures by the modified distinct element method,* Struct. Eng./Earth. Eng. Vol. 6, No. 2, pp 283s-294s. J.S.C.E.

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