DUCTILITY REQUIREMENTS FOR STRUCTURES IN SEISMIC AREAS OF CENTRAL EUROPE

F. P. Müller[I)] and E. Keintzel[II)]

SUMMARY

The required ductility factors of nonlinear one-degree-of-freedom systems, corresponding to earthquakes in the magnitude range characteristic for the seismicity of Central Europe and having the MSK intensity levels of I = 7 and I = 8, are deduced. Computations are carried out for both elasto-perfectly plastic and elasto-plastic stiffness degrading systems with different yield strength levels. The influence of soil-structure interaction on ductility requirements is also analysed. Diagrams for the determination of the required ductility of a structure as a function of its effective strength are given.

INTRODUCTION

Various investigations have shown that ductility requirements for structures in seismic areas depend on the intensity level of the ground acceleration, the yield strength and the damping of the structure as well as the duration of strong ground motions. Because the latter increases with earthquake magnitude, the determination of ductility demands have to take into account, beyound other parameters, also the magnitude of expected earthquakes. In several studies ductility demands corresponding to earthquakes of large magnitudes (7 or greater) are derived. They will, however, be exaggerated for structures situated in regions characterized by a lower seismicity. In the following the required ductility factors corresponding to earthquakes in the magnitude range of M = 5 to M = 6, which is the characteristic range for the seismicity of Central Europe, are deduced.

EARTHQUAKE EXCITATION

The considered earthquake excitation has been represented preliminarily by six accelerograms corresponding to three real earthquakes in the aforementioned magnitudes range: San Francisco Golden Gate Park 1957.3.22 (I = 7, M = 5.3), Hollister (Calif.) 1949.3.9 (I = 7, M = 5.2) and Helena (Montana) 1935.10.31 (I = 8, M = 6). The effect of earthquake intensity is introduced multiplying the Fourier amplitude spectra of accelerations (FS) for an increase of intensity $\Delta I = 0.5$ by the approximate values of an amplification factor α, represented in Fig. 1. These values, depending on magnitude and vibra-

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[I,II)] o.Prof.Dr.-Ing. and Dipl.-Ing. respectively, Institut für Beton und Stahlbeton, Universität Karlsruhe (TH),
Am Fasanengarten, D 7500 Karlsruhe 1, Germany

tional period, have been derived from the relations given in [1]. In Fig.2 the mean response spectra of the accelerograms obtained in this way (solid lines) are compared with those proposed in [2] for the magnitude range of M = 3 to M = 7.5 and different confidence levels p (dashed lines).

STRUCTURAL MODEL

For the derivation of ductility factors a collection of nonlinear one-degree-of-freedom systems with the damping ratio D = 0.05 and vibrational periods T in the range of 0.2 to 3.2 s has been analysed under the acceleration time histories mentioned before, corresponding to the MSK intensity levels of I = 7 and I = 8. Computations are carried out for elasto-perfectly plastic (EP) systems, representative for steel structures, and for elasto-plastic stiffness degrading (SD) systems, defined as in [3] , representative for reinforced concrete structures. The yielding force of any system, having the weigth G, is assumed to be $F_y = cG$.

SOIL-STRUCTURE INTERACTION

For analysing the influence of soil-structure interaction on ductility requirements a nonlinear structure ist considered, supported at the surface of a homogeneous, elastic halfspace. The vibrational period of the soil-structure system is denoted by T and that of the rigidly supported structure by T_o. The displacement response of the system to ground shaking is computed, taking into account the energy dissipation in the soil due to radiation and material damping, according to [4], by means of an effective damping ratio. Computations are carried out for different values of the ratio T/T_o and of the ratio h/r between the heigt of the structure and the radius of its foundation.

NUMERICAL RESULTS AND CONCLUSIONS

Recommended ductility factors μ, corresponding to different yield strength papameters c of both rigidly and flexibly supported structures ($T/T_o = 1$ and $T/T_o > 1$ respectively) are given in Figs. 3 to 5. They have been determined as the mean values of the required ductility factors, calculated for the chosen acceleration time histories. Rigidly supported systems have been analysed in the EP and also in the SD hypothesis, flexibly supported systems in the SD hypothesis only. It can be seen that, as already stated by verious authors, ductility requirements of EP and SD systems are very similar. It is also shown that the soil-structure interaction can decrease the required ductility of stiff, squatty structures, its influence being negligible in the case of flexible, slender systems. Since the ductility factors μ, calculated for flexibly supported structures refer to the entire soil-structure system, where the soil is assumed to remain in the elastic range, the ductility factor of the structure only must have the magnified value $\mu_1 = (T/T_o)^2.(\mu-1) + 1$.

The numerical values represented in Figs. 3 to 5 may be used at the design of antiseismic structures. When the considered yielding forces F_y are compared with the design forces obtained from the application of seismic codes, ductility requirements for code designed structures can be set up. It can be deduced also in what degree the ductility may be reduced in the case of structures at which the effective strength exceeds, for different reasons, the strength required by seismic codes. In this way both strength and ductility of structures can be chosen simultaneously, adequate to the relative low seismicity of Central Europe, thus avoiding any exaggerations in connection with the consideration of higher magnitude levels.

REFERENCES

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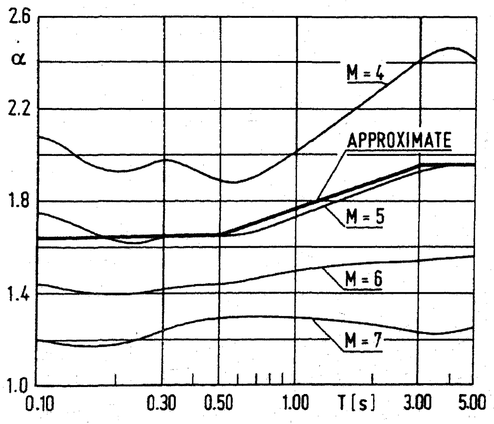

Fig. 1 Amplification factors of FS for ΔI = o.5

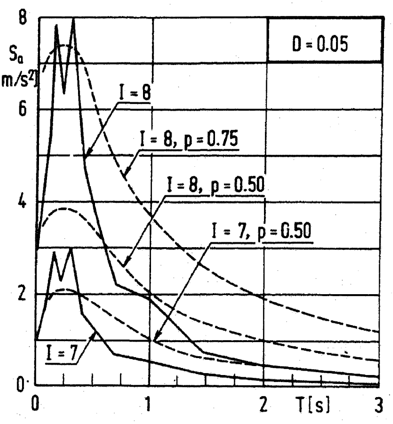

Fig. 2 Mean acceleration response spectra

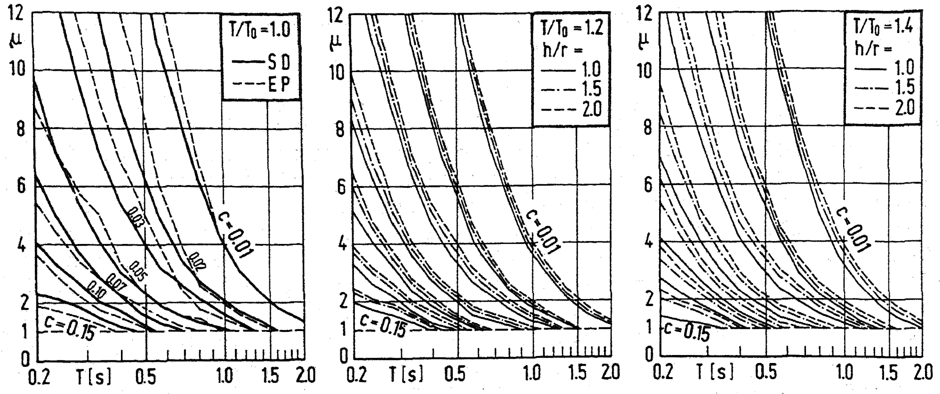

Fig.3 Ductility factors for I = 7 (c = 0.01; 0.02; 0.03; 0.05; 0.07; 0.10; 0.15).

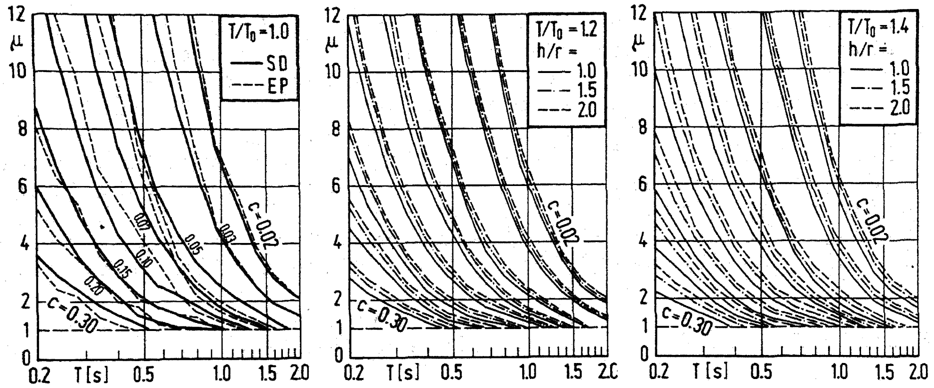

Fig.4 Ductility factors for I = 8 (c = 0.02; 0.03; 0.05; 0.07; 0.10; 0.15; 0.20; 0.30)

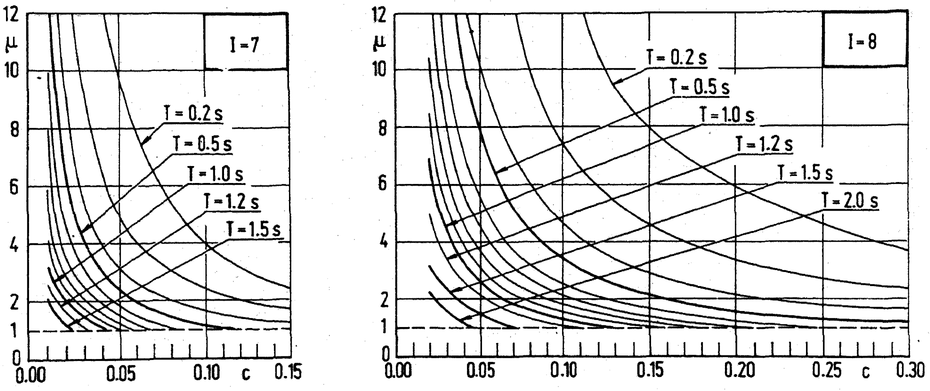

Fig.5 Ductility factors for rigidly supported SD systems (T/T_o = 1.0)