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DAMAGE ASSESSMENT FOR SEISMIC RELIABILITY ESTIMATION OF STRUCTURAL STEEL ELEMENTS

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INTRODUCTION Efficient and practical damage assessment of structural systems undergoing seismic excitation seems to be of great importance, since the economic effects of earthquake damage in certain areas can be quite significant. Therefore it is essential to assess the expected physical damage level for elements of structural systems, which might finally enable improved general reliability/risk estimation. The investigations in this study are focused on the very low cycle fatigue range (10-20 cycles of repetition) because of its importance with respect to earthquake engineering damage assessment. The damage assessment at the present step of investigation is confined to structural steel elements under cyclic axial loading which can be considered to reflect the behavior of truss members, braces and/or their components. All developments are based on experimental investigations in order to verify the damage model as close to the real physical behavior as possible. Special attention is given to different types of failure modes, e.g. failure due to: a) compression and bending, b) tension and bending, c) pure tension. Due to the presence of instability effects the damage modeling refers to structural damage rather than to material damage.

EXPERIMENTAL INVESTIGATIONS Simple but fundamental specimens with rectangular cross section are selected to simulate local buckling behavior of thin plate elements of structural members. The experiments are performed up to complete failure of the specimen, in order to observe the structural failure phenomena in detail. On both ends pin-supported conditions have been selected, which could be realized by the loading system suggested in [1]. Load was applied to the specimens with controlled axial displacement patterns. The specimens' behavior was monitored by strain gages and displacement meters. For further details on test set up and experimental investigations it is referred to [2].

DAMAGE ASSESSMENT ON THE BASIS OF EXPERIMENTAL INVESTIGATIONS The main drawbacks of many existing damage parameters are related to the lack of reflecting the loading history and the assumption of linear damage accumulation (e.g. Miner Rule, etc.). Linear damage accumulation might be true in special cases, while neglecting the loading history may lead to considerable errors in structural damage estimation. Energy related damage criteria seem to be most attractive in this situation since they reflect loading history and type of failure mode. For the general application of a

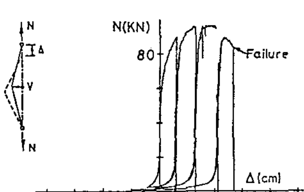

Fig.1: Axial Load vs. Displacement Relation

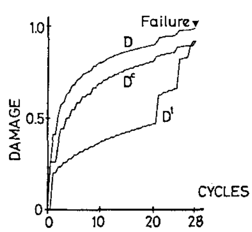

Fig.2: Damage Parameter; Specimen No. 1

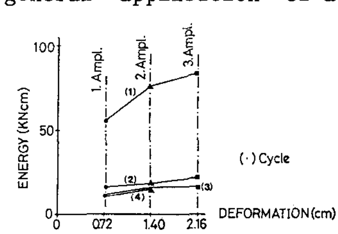

Fig.3: Energy Dissipation per Cycle; Specimen No. 1

damage model with respect to different kinds of failure modes, it appears rather efficient when expressed in terms of properly nondimensionalized variables. A most promising damage indicator has been suggested in [3], where the monotonic failure curves are used as the only normalizing parameters and the larger part of damage is related to the first cycle on each amplitude level. This damage indicator was developed for reinforced concrete members, but the main principles can be easily applied also to structural steel. Note that failure in this investigation always refers to breakage. Different amplitude levels in tension and compression have been applied to specimen No. 1 (see Fig. 1). Fig. 2 shows the calculated degree of damage (D) using this model based on the mentioned test results, where D=1 means complete failure. Clearly the contributions of damage from compressive (D^c) and tensile (D^t) deformation can be seen. The sudden increases of damage at the 20th and 24th cycle are related to the first cycle at increased loading amplitude level. At this step the larger part of the energy is dissipated (see Fig. 3). The assumption of the damage model that the largest part of damage is related to the first cycle at each amplitude level, therefore, seems to be confirmed. The loading history of specimen No. 7 is confined to the compressive deformation range, consequently only "compressive damage" will occur, which is shown in Fig. 4. Additionally a large contribution to damage

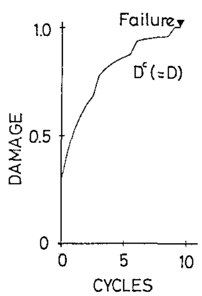

Fig.4: Damage Param.; Specimen No.7

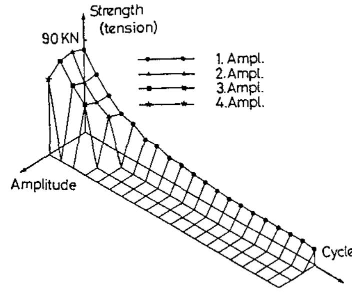

Fig.5: Strength Deterior.; Specimen No.1

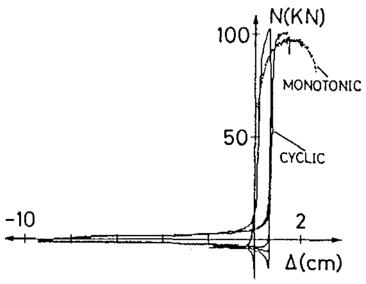

Fig.6: Load-Displacement Curves; Specimen No. 2 and 3

from the initial loading cycle could be found. In calculating the damage contributions it can be noticed that the shape of each curve is somehow sensitive to the normalizing values from monotonic loading, while the degree of calculated damage is about the same. Obviously the model seems to be quite consistent to the final damage state, but so far there are some doubts about the intermediate range. Especially with respect to intermediate damage states and combined damage, strength deterioration properties seem to be of importance. However considering strength deterioration in the experimental investigations (see Fig. 5), it can be noticed that a failure definition related to a fixed residual strength capacity is not meaningful. Furthermore during the experimental investigations it could be noticed, that the maximum strength capacity might occur at different amplitude levels dependent from the loading history. In some cases the monotonic load-deformation curves even do not provide the envelope curve of the cyclic loading. In Fig. 6 this situation is illustrated in comparing the load-displacement curve of specimen No. 3 with the monotonic one. It can be noticed, that specimen No. 3 shows descending strength at lower displacement level than in monotonic testing.

OUTLOOK AND CONCLUSIONS The so far performed experimental investigations revealed that there is a close relation rather than a one to one relationship between damage and energy, but a strong dependence to loading history and amplitude relation of compressive and tensile range. Therefore the ongoing research on damage assessment is focused on the combination of energy considerations with strength deterioration as well as deformation level investigations to provide a meaningful damage parameter for intermediate damage states. The development will be verified by continued experimental investigations to ensure a real physical interpretation of different calculated damage states.

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