INELASTIC BEHAVIOR OF REINFORCED CONCRETE STRUCTURES SUBMITTED TO INDUCED VIBRATIONS OF AIRCRAFT IMPACT OR GAS CLOUD EXPLOSION

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SUMMARY

According to the German RSK-Guidelines (Reactor Safety Commission) safety-related equipment of nuclear power plants in Germany as well as those reinforced concrete structures where a collapse will involve functional restriction of the safety-related equipment are to be designed against the induced vibrations of so-called "External Influences" like earthquake, aircraft impact and gas cloud explosion. This is normally done by calculating the time histories at several points of a building and then generating floor design spectra.

In contrast to an earthquake which may excite a structure for several seconds the impact duration of the postulated RSK-aircraft crash is only 70 milliseconds and of the gas cloud explosion only 300 milliseconds. Thus the induced vibrations typically have only one or two peaks and then decay very quickly like a damped sinusoidal motion. A special feature of the aircraft impact is that as a result of the arbitrary polygonal loading curve, made up of several straight line segments, very high frequencies (upwards of 10 Hz to 50 Hz) are excited. This is the fundamental frequency range of many reinforced concrete slabs and walls. The correspondent accelerations of the floor response spectra are especially for relatively small buildings, such as the emergency feed building, as high as 5 to 10 g. This will lead to considerable additional reinforcements if the internal forces are calculated by multiplying these accelerations with the equivalent masses.

According to German rules, safety-related reinforced concrete structures of nuclear plants are designed ductile by considering special requirements for minimum/maximum reinforcement and construction. Thus in case of dynamic overtressing these reinforced concrete structures will not fail brittle but plastify.

The purpose of this paper is to show, that even with low plastification ratios a high reduction of reinforcement is possible. This is done by calculating elasto-plastic floor response design spectra for different plastification ratios on the basis of typical time histories of aircraft and gas cloud induced vibrations. Proof can be furnished, that with a plastification ratio of about two there will be nearly no resonance amplification in the response spectra. This is a typical result of the self-regulating effect of plastification.

Therefore the following will be recommended for the design of reinforced concrete structures against the induced vibrations of short-time impact:

1) to consider no resonance amplification phenomena for these will not occur, when in case of overstressing the structures will behave ductile;
2) to make a simplified analysis with the peak accelerations of the floor time histories, without calculating the fundamental frequency of the structure (in most cases the minimum reinforcement or the reinforcement for other loading cases will be adequate);
3) to calculate the elasto-plastic response only in those cases, where the additional reinforcement resulting from the above mentioned method is uneconomic.

The paper shows, that the total plastic deformations remain relatively small when compared with deformations, which are calculated by elastic response design spectra. Recommendations are made for the allowable plastification ratios and the consequences are discussed in detail.