COMPUTATION OF HCLPF PARAMETERS FOR 3D SHELL MODELLED RC STRUCTURES – SEISMIC CERTIFICATE

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Summary

The objective of this article is to present a practical method for calculation of the parameter of marginal seismic resistance, which can be used to assess the slab-wall reinforced concrete constructions during the process of finishing the 3rd and 4th block of the nuclear power plant Mochovce (Slovak Republic). This parameter HCLPF (some kind of seismic certificate) is used for the assessment of seismic resistance of buildings, equipment and systems in nuclear power plants. This article is a theoretical description of the assessment and a subsequent application of the theoretical solution to practical calculations and assessments of seismic resistance of reinforced concrete shell constructions.

Keywords: European standards, concrete structures, FEM, HCLPF, seismic design, shell

1 Introduction

Determination of the value specifying the achieved marginal seismic resistance, the so--called HCLPF parameter, is required for the assessment of the seismic resistance of buildings, equipment and systems in nuclear power plants, e.g., in completion of the 3rd and 4th block of Mochovce (hereinafter MO34). For the completion of Mochovce we denote this parameter $HCLPF_{MO34}$. The final value of the parameter $HCLPF_{MO34}$ (given for the ultimate way of failure) has to be at least equal to the value of PGA (peak ground acceleration) to guarantee the seismic resistance at the required level. If this condition is implemented, the assessed component or construction element will be satisfactory from the point of view of strength. In this contribution we submit a solution which was developed for slab-wall reinforced concrete systems consisting of slabs, walls, central cores where we model the reinforced concrete construction elements as 3D Shell elements in computational MKP models.

2 Definition of parameter HCLPFMO34 (High confidence in low probability of failure)

The first step to calculation of $HCLPF_{MO34}$ is the calculation of safety coefficient F_s, which corresponds to the multiple of the resultant seismic reaction determined for a value of PGA (peak ground acceleration), in which the decisive acceptance criterion used for the assessment of the given component or resistance of the construction element will be depleted. For F_S it holds that:

$$F_S = \frac{C - R_{NS}}{R_S} \tag{1}$$

Where: C capacity of the component of construction element
R_{NS} resultant reaction to the non-seismic load
R_S resultant reaction to seismic load defined by the value of PGA
F_S safety coefficient.

For the calculation of parameters of marginal seismic resistance HCLPF the following relation holds:

$$HCLPF_{MO34} = F_S \,.\, PGA\ (g) \tag{2}$$

The resultant value of parameter $HCLPF_{MO34}$ (determined for the decisive process of damaging) must be at least equal to the value of PGA to guarantee the seismic resistance at the required level. If this condition is satisfied, the assessed construction will be acceptable from the point of view of strength.

Thus, it is apparent that the parameter $HCLPF_{MO34}$ characterises the assessed construction as a whole from the point of view of its weakest component and represents the maximum possible value of PGA at the same level of dead and live load. In case we wanted to set the given construction in some other place (geographically or within the site), for which the design value PGA was different, from the parameter $HCLPF_{MO34}$ it is possible to state whether the construction is acceptable from the point of view of strength even without further static analysis.

3 Solutions for concrete shell components in compliance with STN EN 1992-2

The attachment MM deals with the theoretical solution of laminated concrete sandwich elements. Its recommended use is for the revision of the walls of box bridge girders in the parts where the simplified beam analogues cannot be used. Three layers are defined in the sandwich model : two external layers transfer membrane effects formed by n_{Edx}, n_{Edy}, n_{Edxy}, m_{Edx}, m_{Edy}, m_{Edxy}; and the inner layer transfers shear forces v_{Edx}, v_{Edy}. The thickness of individual layers can be determined by iterative method.

6 components of internal forces n_{Edx}, n_{Edy}, n_{Edxy}, m_{Edx}, m_{Edy}, m_{Edxy} are further transferred to membrane stresses in individual external layers by means of particular relations of the technical theory of elasticity (fig. 1).

Furthermore it is possible to dimension the individual layers of shell model as separate two-dimensional membrane elements by combining inner forces determined by linear analysis of the finite element method. The membrane elements are stressed only in the level of forces namely σ_{Edx}, σ_{Edy}, τ_{Edxy}. Actual assessment of membrane elements has been considered in STN EN 1992-2 Article 6.109.

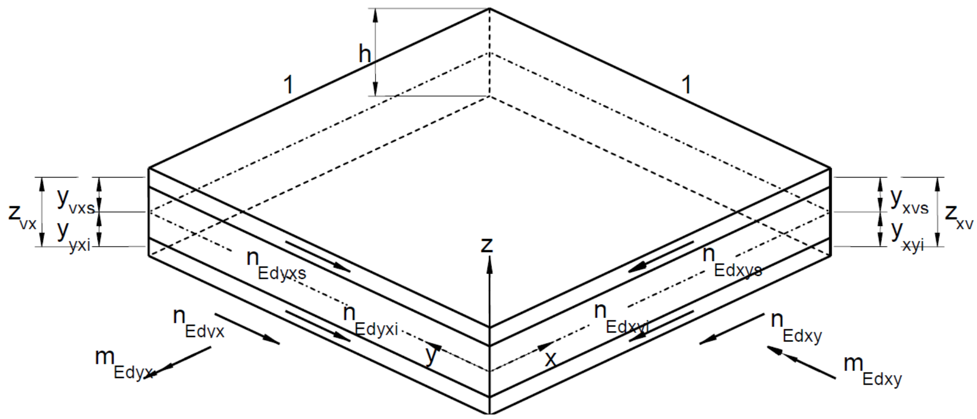

Fig. 1 *The effects of membrane shear forces and moment of torsion in external layer [4]*

4 Practical calculation of marginal seismic resistance of reinforced concrete shell components

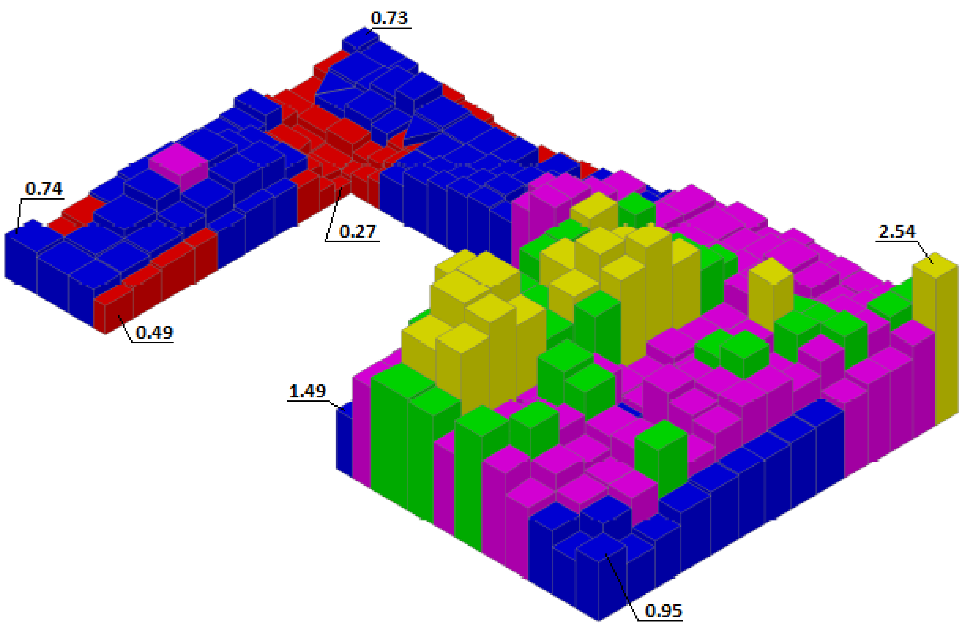

Fig. 2 *Calculated course of parameter HCLPF on selected concrete slab with a hole*

The objective of this task is to find the marginal seismic resistance of reinforced concrete structures on the boundary of failure of their weakest member. Thus we are searching for a multiplier (safety level FS) of linear seismic combination, the application of which with constant/dead load will cause the failure of construction in at least one finite element. The weakest member of the construction is considered to be the finite element with the lowest safety level FS, to which the value HCLPFMO34, characterizing the whole construction from the point of view of seismic resistance, corresponds when the element is multiplied by basic acceleration.

Considering the non-linear character of the task and complexity of the whole algorithm for the assessment of one shell element (in compliance with STN EN 1992-2), the analytical solution of the task would be very complicated and hard to monitor.

The task can also be solved iteratively and considering the fact that finite element load is imported from FEM system, the solution in Excel seems to be the most practical and fastest. The calculation proceeds automatically in individual stages, assessing elements up to the moment when the safety level of all finite elements has been found and the lowest one constitutes the seismic resistance. The accuracy of the solution is determined by the area of marginal resistance and the magnitude of the iterative step. The area of marginal resistance means the interval of utilization of the construction (e.g., 95–100 %), when the iterative calculation for the given element is completed. Higher accuracy of the calculation is naturally more time-consuming. For several thousand finite elements the calculation can take a few minutes. In fig. 2 we can see the course of marginal seismic resistance on the selected concrete slab with an opening.

5 Conclusions

The calculation of marginal seismic resistance of reinforced concrete shell constructions is a difficult task, especially in comparison to the calculation of parameter $HCLPF_{MO34\ for}$ steel rod constructions with which we have extensive experience. As this parameter has been used for the assessment of seismic safety of nuclear plants and its structural members a responsible approach is imperative. The use of the system of calculation is universal; import of data is possible from any FEM CAD system which supports the export of the results in the format of “delimited files”.

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