Probabilistic approach to the assessment of composite steel-concrete structure

P. Kesl [1]

[1]*University of West Bohemia in Pilsen, Faculty od Applied Sciences, Department of Mechanics,*

Univerzitní 8, 306 14 Plzeň, CZECH REPUBLIC, kesl@kme.zcu.cz

Abstract: Probabilistic approach to the assessment of composite steel-concrete structure of the building DT Plzeň. A brace of symmetrical "I" ross- section of steel S 235, C20/25 concrete. To assess the structure, we performed simulation with the use of the SBRA probability Method by Anthill software and with subsequent comparison ofultimate load results with percentage of use of most stressed part of the segment determined through calculation by Fine-EC-EC4 program.

Keywords: Reliability of structures; steel-concrete; composite; probability of failure; design probability; simulation; defining a limit state; Simulation-Based Reliability Assessment (SBRA Method).

1 Introduction

For the composite steel and concrete ceiling construction in the building of the Technology Centre - DT Pilsen a symmetrical rolled profile IPE 220-240 of steel grade S 235 and reinforced concrete slabs C20/25-25/30-XC, class reinforcement B550B was used. On this structure calculation is carried out according to DIN-EN-1991 report profile DIN-EN-1994 inner strength Fine-EC-2D, 3D, and subsequent optimization probabilistic method SBRA-program Anthill with the probability of structural failure Pf (i) ceiling segment (Fig.1) in used.

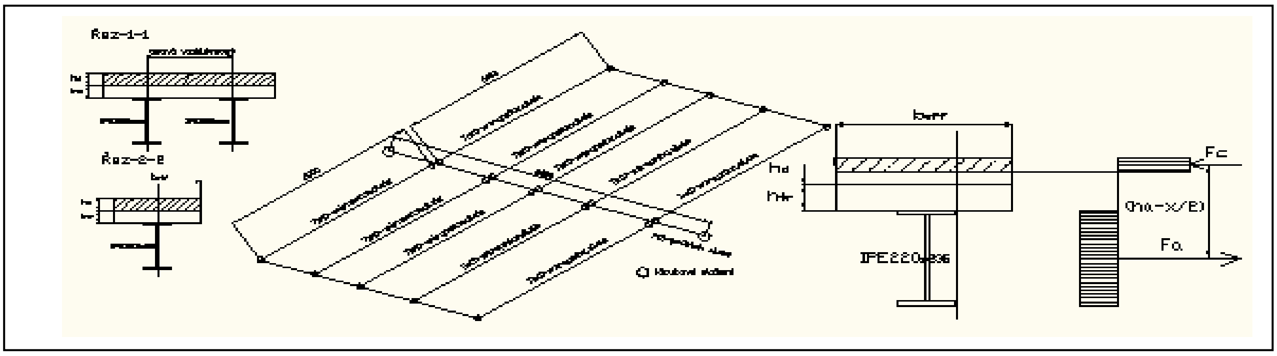

Fig. 1: Static scheme ceiling of composite structures, TS (i), P (i)

2 Assessing structures

The composite rod of symmetric cross section as a ceiling segment (Fig. 1) of rolled IPE 220- 240 of steel grade S 235, and the concrete slab of concrete C20/25-25/30-XC ,class reinforcement B550B, the load width of 2000 mm and span of 6000 mm was analyzed for different load conditions (ZS, S, G, W, Q, A (i)) i = 1 to 6). Decisive load combinations was determined by Fine-EC program and the structural response for each load was analyzed for the TS-component (i), P(i) in accordance with a combination of theory I. , II. regulations.

2.1 Equations - Model in Anthill-SBRA method:

$$V_{smyk} = V_{ed} / V_{rd} \,, \quad (1) \qquad V_{rd} = \frac{A_V \; A\,\mathrm{var} \dfrac{F_y \,\mathrm{var}}{\sqrt{3}}}{10} \quad (2)$$

V_{ed} $[N]$ .... design combination of shear forces

V_{rd} $[N]$ .... resistance of Shear

$$M_{ohyb_{adol}} = M_{ed} / M_{Pl\,rd\,a} \,, \quad (3) \qquad M_{Pl\,rd\,a} = A \; A_{\mathrm{var}} \; f_{yd} \; z \; r \left(10^{-3}\right)[Nm] \quad (4)$$

$$Ohyb_{,adol} = \sigma_{,adol} / f_{yd} \quad (5) \qquad \sigma_{,adol} = \left(\left(M_{ed} / I_y\right) z_{dol}\right)\left(10^{-3}\right) \quad (6)$$

M_{ed} $[Nm]$ .... design combination of bending moment

$M_{Pl\,rd\,a}$ $[Nm]$ .... the reduced bending resistance in cross-section

Ohyb,adol [%] ……..... utilization of the cross-section under the action of bending moment

M_{ed} $[Nm]$ .... design combination of bending moment

$\sigma_{a\,dol}$ $[MPa]$............... educed resistance sectional flexural

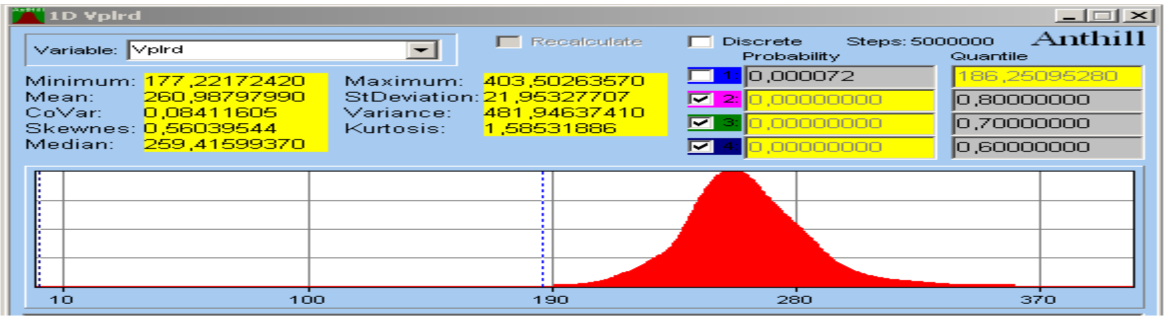

Fig.2: Shear capacity sectional *Vpl rd [N]*

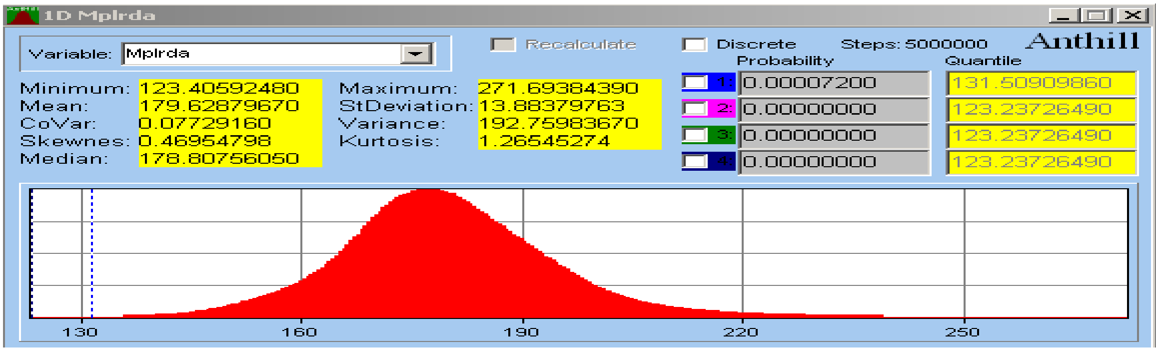

Fig.3: The reduced bending resistance in cross-section $M_{Pl\,rd\,a}$ $[Nm]$, $M_{Pl\,rd\,c}$ $[Nm]$

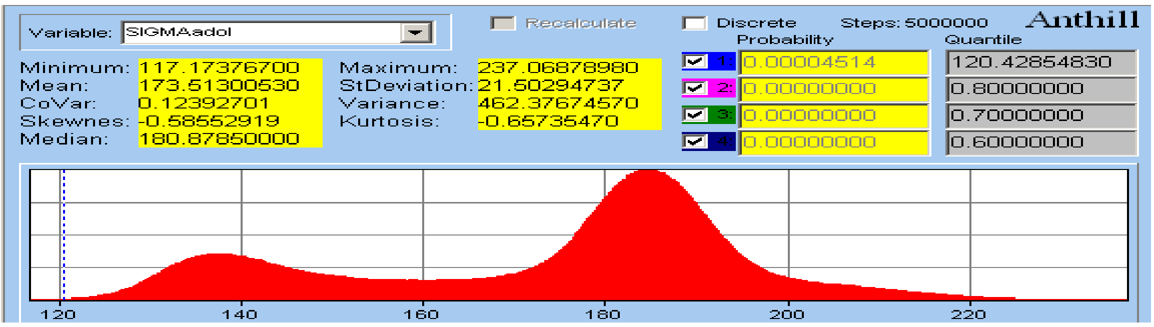

Fig.4: The resulting reduced stress $\sigma_{a\,dol}$, $\sigma_{c,hor}$ $[MPa]$

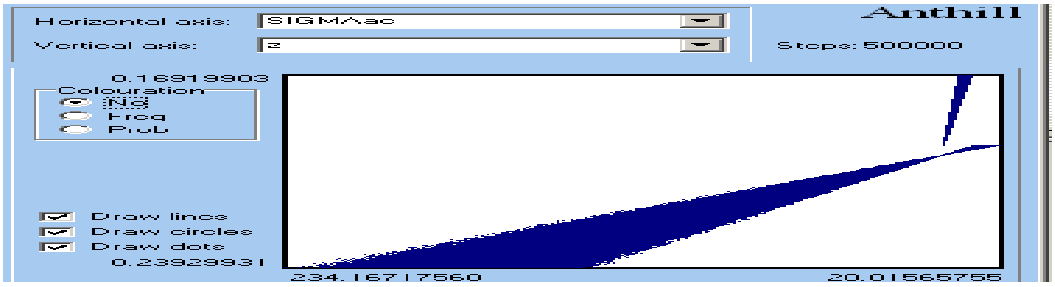

Fig.5: Tension in cross - elasticity [MPa]

The determined value for the probability of failure Pfd(i) = 0.000072 are: according to the model diagram - plasticity (Fig.3) the torque is 131.51 kNm, and according to the model diagram – elasticity (Fig.4) the stress is 173,513 MPa.

2.2 Assessment of the cross section on the probability of failure - Pf(i) - (SF(i))

For the simulation interval and determining the failure probability Pf (i) or SF (i) of the steel-concrete profile a set of calculations (series 1, series 2, series 3) was performed for the different number of simulation steps: 500.000, 1.000.000, 2.000.000, 5.000.000, 6.000.000 cycles. Category 4 is the design life, life of 50 years, the consequences class CC2, maintenance IL2, these values are Pfd(i) (MSU) = 7.2 (10^{-5}) Pfd(i) (MSP) = 6.7 (10^{-2}). The failure probability on the structure is in the interval with the number of cycles 5.000.000 is Pf(i)= (from 1,12(10^{-5}) to 1,375(10^{-5})) (Fig.6), or the use of the cross-section of 94% -97% (Fig.7).

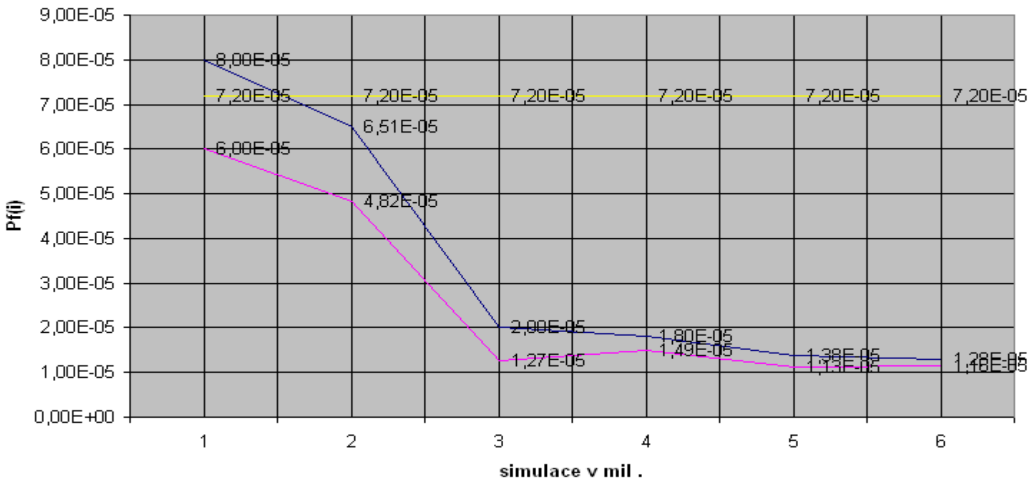

Fig.6: The course of the failure probability Pf (i), SF(i) the number of simulations

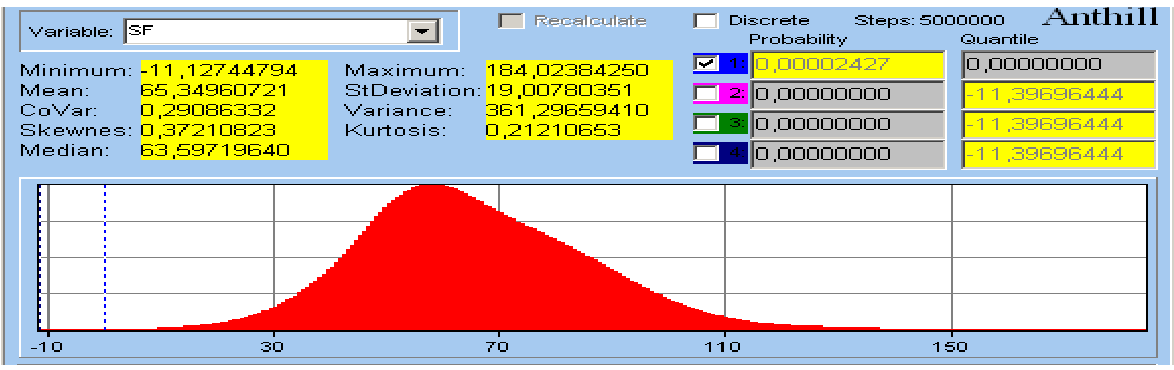

Fig.7: Probability of failure Pf(i), SF(i)

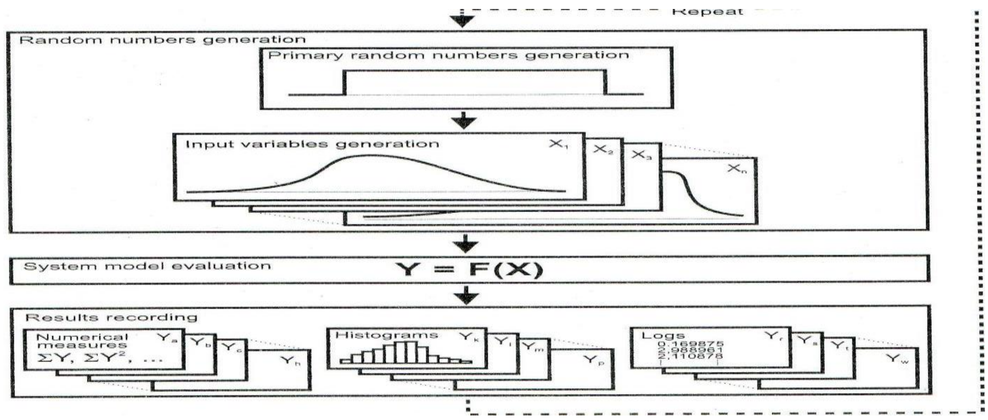

Fig. 8. Simulation model of solved beam

3 Conclusion

Summary and conclusions - evaluation of results obtained using SBRA and EC4. For the comparison of results obtained by DIN-EN-1994 and SBRA methods (fig.2,3,4,5,6,7) follows that using probabilistic SBRA method leads to savings of material in extremely stressed ceiling segment. This conclusion is achieved by a different understanding and approach to the calculation and design, which is based primarily on the probability theory and simulation (Fig.8). Taking into account the influences acting on the structure, external and internal conditions and structure usage savings in material and finance are obvious (Tab. 1).

Tab. 1: Comparison of results extremely stressed segment

Equations	Results obtained by calculating		Difference in %.
	DIN-EN-1994	SBRA Anthill	
Vpl,rd	48,43%	45,50%	+2,93%
Mpla,Rd, Mplc,Rd, plasticity	88,00%	75,00% ÷ 80,00%	+8,00% ÷ +13,00%
$\sigma_{a,dol}$ $\sigma_{c,hor}$, elasticity	96,00%	89,00% ÷ 90,00%	+6,00% ÷ +7,00%
probability of failure Pf(i)	Pfd(i)=0,000072	(1,12*10-5 ÷ 1,375*10-5)	Probability of failure < Pfd(i)
% Utilization, fault - is Pf (i)	-	(94,00% ÷ 97,00%)	Values at the extreme limits
% Utilization, fault - not Pf (i)	Pf(i)=0	(cca 90,00%)	Recommended value assessment.

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