Optimization Study of Beam with Sudden Profile Change

Jan Hlavacek; Prague - Czech Republic;
jhlavacek@pro-eng.com, http://www.pro-eng.com/

This example deals with application of SBRA (Simulation Based Reliability Assessment) method for safety assessment of a welded steel beam with a sudden profile variation. Close attention is paid especially to the determination of the position where the profile changes.

Assignment

The beam is simply supported. Span is L = 4 m, material grade is steel S235. The beam is exposed to two uniformly distributed loads. The design values are: dead load g = 10 kN/m, long lasting live load q = 8 kN/m. Assess I-profiles of this steel welded beam (see *Fig. 2*) regarding the bending moment. Determine the position where the profile is to be changed with respect to the material savings. Lateral-torsion buckling of the beam is prevented. Do not assess the serviceability limit state. The design probability of failure is $P_{f,lim} \leq 0.00007$.

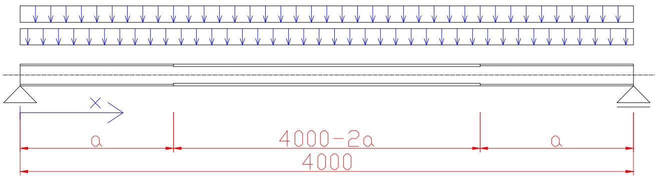


Fig.1 Beam scheme

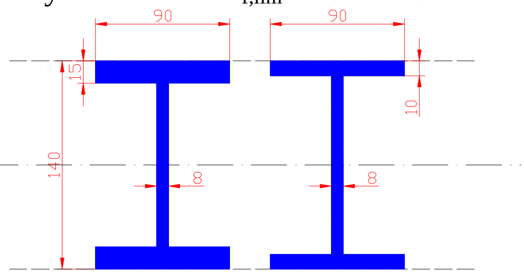


Fig.2 Profile 1, Profile 2

Structure Response to the Load 'S'

The variable value of the load is equal to the product of its maximum value and the coefficient expressing its variation by the assumptive distribution, then $g = 10$ kN/m $\cdot\, g_{var}$, $q = 8$ kN/m $\cdot\, q_{var}$. Individual distributions follow in the chart (*Fig.3*).

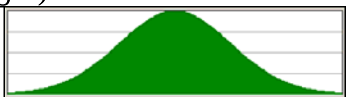
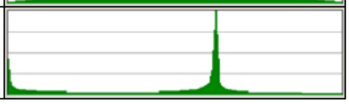
dead load g_{var} distribution	dead1.dis	
long lasting load q_{var} distribution	long1.dis	

Fig.3 Variables of the response

The bending moment behavior along the beam $M_x = ½ \cdot (g + q) \cdot (L \cdot x - x^2)$ is traced by *AntHill* [1] software. The variables taking part in this simulation are g, q.

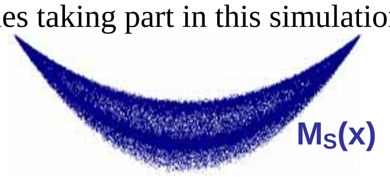


Fig.4 Structure response, dispersion of the bending moment M_x along the beam

Structure Resistance 'R'

The variable value of the steel yield stress is equal to the coefficient expressing its variation by the assumptive distribution, then $f = f_{var}$. The variable values of the profile moduli are equal to the products of their nominal values and the coefficients expressing their variation by the assumptive distributions, then $W_1 = W_{1,nom} \cdot W_{var}$, $W_2 = W_{2,nom} \cdot W_{var}$. Individual distributions follow in the chart (*Fig.5*).

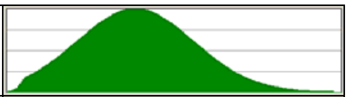
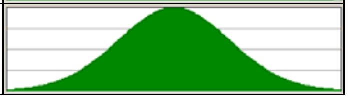
steel yield stress f_{var} distribution	st235.dis	
profile moduluses W_{var} distribution	n1-05.dis	

Fig.5 Variables of the resistance

The nominal values of the cross-sections properties are $W_{1,nom} = 1.64E^{-4}\ m^3$, $W_{2,nom} = 1.25E^{-4}\ m^3$. The profiles 1 and 2 are displayed on *Fig.2*.

The structure resistance is defined as the product $M_r = W \cdot f$, than $M_{r1} = W_1 \cdot f$, $M_{r2} = W_2 \cdot f$.

Assessment

Critical cross-sections, considering the bending moment, are for Profile 1 the center of the beam (x = 2 m), for Profile 2 the place of its sudden profile variation (x = ?).

Profile 1, x = 2 m

In the center of the beam's span is the failure probability $P_f = 0.000053 < P_{f,lim} = 0.00007$. Profile 1 satisfies the requirements, calculated by *AntHill* [1] software.

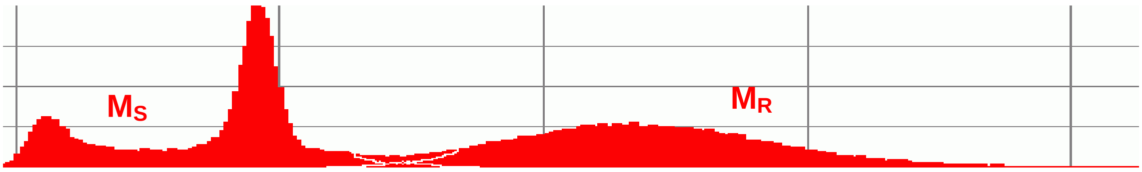
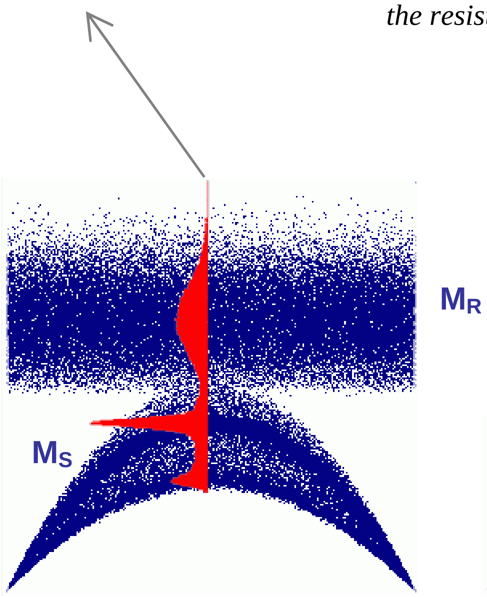


*Fig.6 SFF1, cross-section of Fig.7 in the span center (**x =2 m**), P_f is determined by the intersection of the resistance and response graphs*



Profile 1

x = 2 m

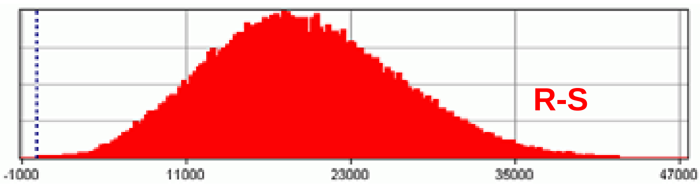


Fig.7 AntHill: response M_x and resistance M_{R1}

Fig.8 SF1 = R – S

Profile 2, x = ? m

With assistance of *AntHill* [1] software, the probability of failures is found in individual positions near the estimated location of the sudden profile change.

M_{R2} profile: **I-140/90-10mm**

x[m]	prob. Pf[0]
0,90	0,0000000
0,95	0,0000000
1,00	0,0000270
1,05	0,0001297
1,10	0,0004193
1,20	0,0018979
1,40	0,0104442
1,60	0,0280406

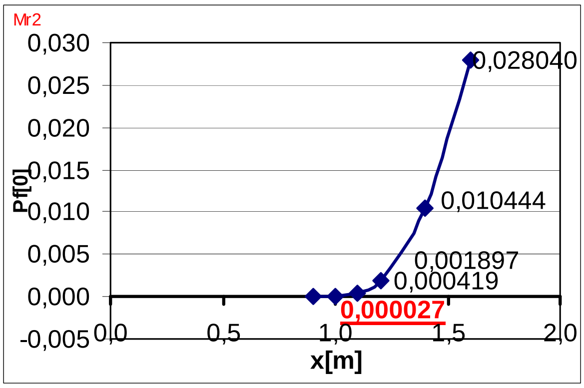


Fig.9 Optimization, probability of failure calculating P_f near the sudden change location

The profile should be changed in position **x = 1 m** from the support. The failure probability in this location P_f = 0.000027 (see *Fig.9*) < $P_{f,lim}$ = 0.00007. Profile 2 satisfies the requirements. Calculated by *AntHill* [1] software.

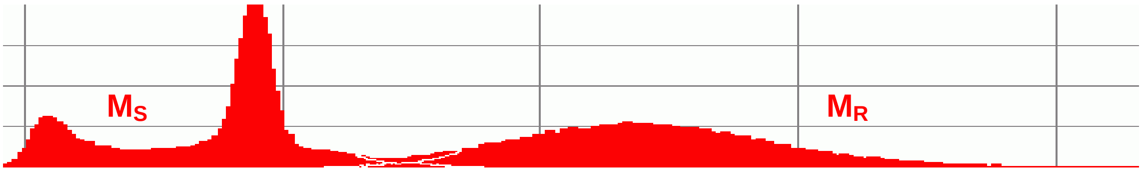
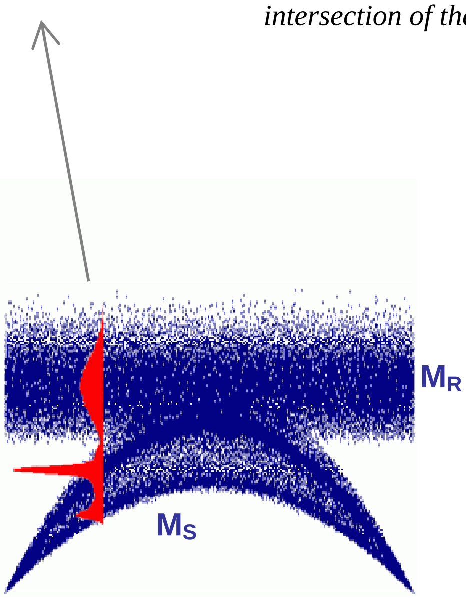


*Fig.10 SFF2, cross-section of Fig.11 in the **x =1 m** position, P_f has been determined by the intersection of the graphs of resistance and response*

Profile 2

x = 1 m



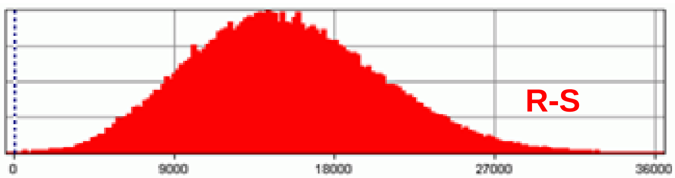


Fig.11 AntHill: response M_x and resistance M_{R2} *Fig.12 SF2 = R – S*

Global Analysis of Profile 1 and 2

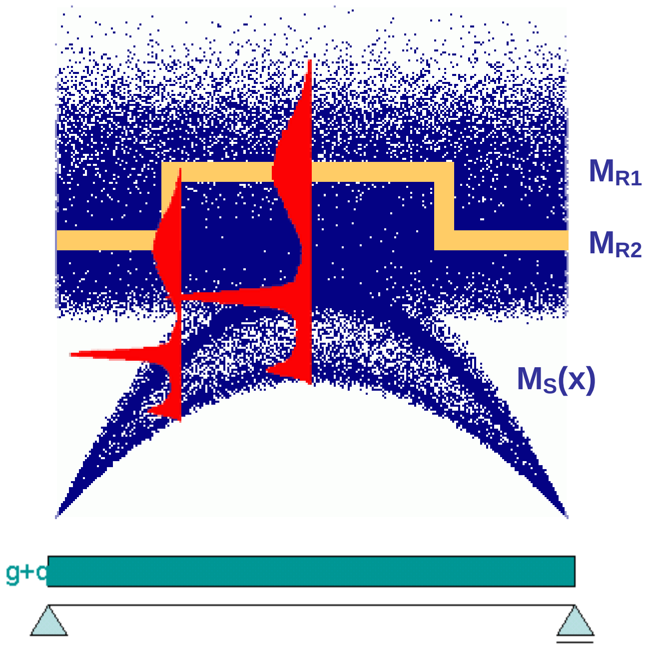


Fig. 13 Response and resistance, bending moments M_x, M_{R1}, M_{R2}

Additional Study

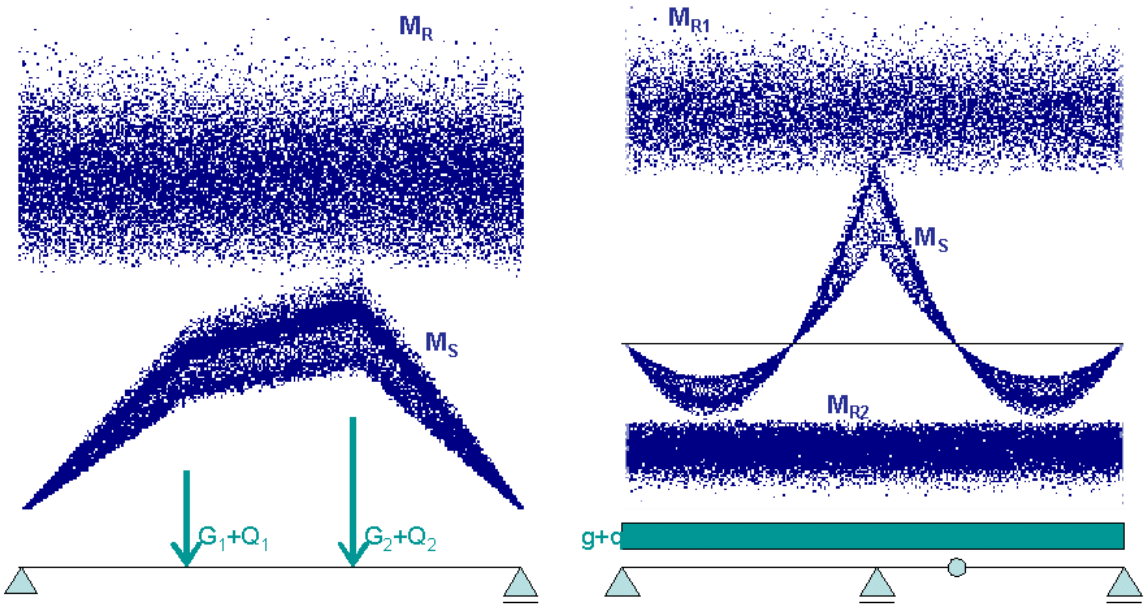


Fig.14 AntHill: response M_s and resistance M_R

Conclusions

This study outlines the opportunity of using SBRA method for the global reliability assessment. The used example is very simple; however, it is possible to asses more complicated statically determined structures.

References

[1] *Probabilistic Assessment of Structures using Monte Carlo Simulation – 1st edition*; editors: P. Marek, J. Brozzetti, M. Gustar; publisher: ITAM CAS CR, Prague 2001