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BUCKLING CURVES OF HOT-ROLLED STEEL SHAPES WITH STRUCTURAL IMPERFECTIONS

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ABSTRACT

Theoretical and experimental researches directed to study the main buckling problems of metal members are carried out at the Istituto di Tecnica delle Costruzioni of the University of Naples (see bibliography 1,2,3,4,5,6,7,8).

The modern approach to the buckling problems requires to take into account structural imperfections, which characterize the actual bars and whose determination must be made in experimental way.

The principal results of experimental investigations on Italian hot-rolled steel shapes are here briefly summarized. Structural patterns of residual stresses have been obtained on the basis of such experimental results. Simulation calculations have provided the buckling curves for the examined profiles with structural imperfections. The simulation curves have been compared to the CECM-ECCS ones (9).

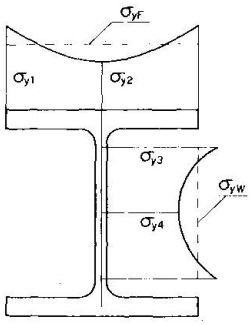
EXPERIMENTAL INVESTIGATION

The hot-rolled I shapes in structural steel Fe 42C, which have been examined, are:

IPE 200; HEA 100; HEB 100; HEM 100;
HEA 200; HEB 200; HEM 200;
HEA 300; HEB 300; HEM 300;

The following groups of tests have been made:

a) Distribution on the cross section of the mechanical charac teristics: yield point, ultimate strenght, elongation, toughness, hardness; the principal scatters of the yield point distribution are shown in fig. 1.



YIELD POINT DISTRIBUTION

	HEA 100	HEB 100	HEM 100	HEA 200	HEB 200	HEM 200	HEA 300	HEB 300	HEM 300	IPE 200
σ_{y1}/σ_{yF}	1,06	1,07	1,07	1,04	1,09	1,06	1,07	1,15	1,08	1,02
σ_{y2}/σ_{yF}	0,90	0,88	0,95	0,99	0,95	0,94	1,10	0,97	0,99	0,97
σ_{y3}/σ_{yw}	0,99	1,01	1,02	1,23	1,31	1,36	1,08	1,98	1,00	0,95
σ_{y4}/σ_{yw}	0,96	0,96	0,99	0,97	0,85	0,82	0,98	1,00	1,05	1,03
σ_{yF}/σ_{yw}	0,88	0,89	0,89	0,88	0,82	0,74	0,91	0,92	0,93	0,82

fig. 1

b) Stub column tests; the lowering of the proportional limits appears from fig. 2

	σ_p/σ_{yF}	σ_p/σ_{yw}	STUB COLUMN TEST
HEA 100	0,86	0,77	
HEB 100	0,82	0,73	
HEM 100	0,99	0,88	
HEA 200	0,86	0,76	
HEB 200	0,71	0,58	
HEM 200	0,82	0,60	
HEA 300	0,74	0,68	
HEB 300	0,81	0,75	
HEM 300	0,52	0,49	

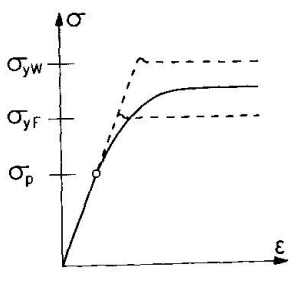


fig. 2

c) Evaluation of residual stresses by means of sectioning test; the interpretation of the experimental results leads to the pattern of fig. 3.

	$\sigma_1=\frac{\sigma_{crf}}{\sigma_{yF}}$	$\sigma_2=\frac{\sigma_{crw}}{\sigma_{yw}}$	RESIDUAL STRESSES PATTERN
HEA 100	0,100	0,104	
HEB 100	0,126	0,150	
HEM 100	0,059	0,099	
HEA 200	0,037	0,560	
HEB 200	0,284	0,480	
HEM 200	0,061	0,242	
HEA 300	0,221	—	
HEB 300	0,202	—	
HEM 300	0,304	0,970	
IPE 200	0	0,680	

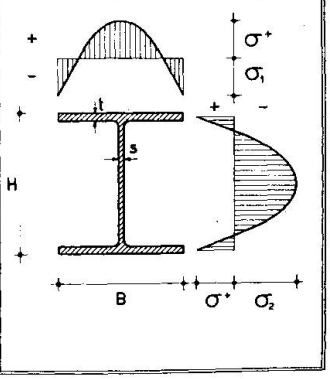


fig. 3

More details on the testing procedures and on the number of specimens are reported in (1), (7).

RESIDUAL STRESSES PATTERNS

The diagrams of residual stresses experimentally obtained have shown that the distributions are deeply influenced by the rotorizing procedure. Residual stresses in the flanges of the same bar, exhibit quite different distributions (fig. 4).

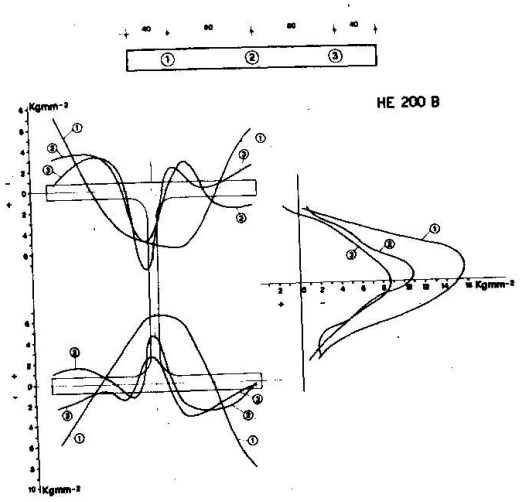


fig. 4

This fact makes impossible the statistical interpretation of the results and out of meaning the theoretical prediction of the thermical forming of residual stresses.

The collection of experimental data for a certain number of specimens makes possible the definition of bands which contain residual stresses for the examined shapes (fig. 5).

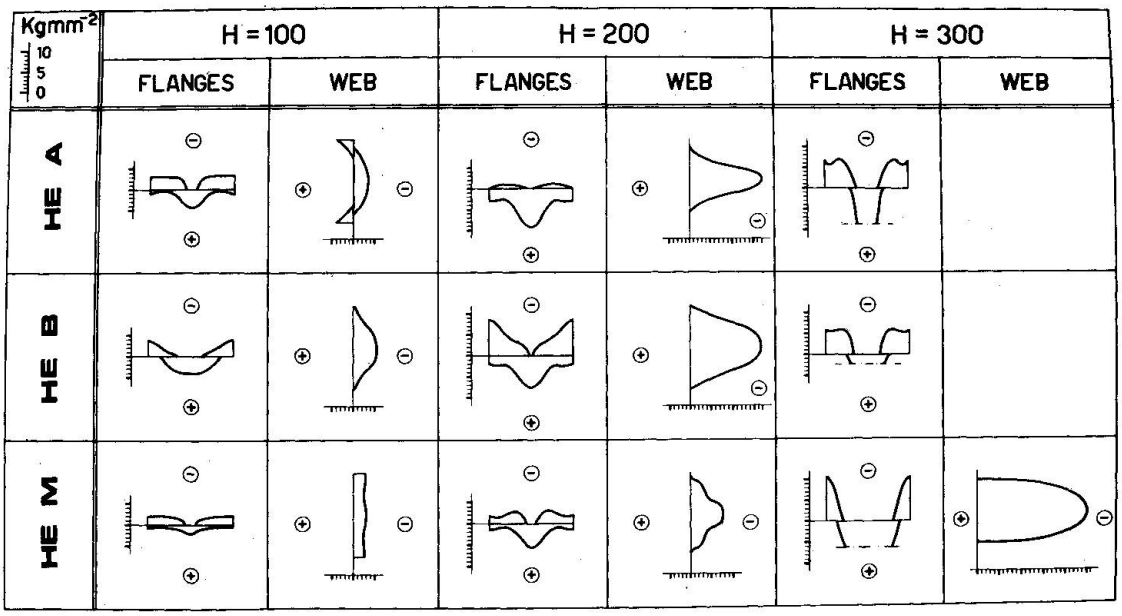


fig. 5

Starting from these data a structural pattern of residual stresses has been proposed, which utilizes the maximum compressive stresses at the edges of the flanges and at the center of the web. The condition that this pattern is in equilibrium leads to the residual stresses distributions shown in fig. 6 (1,5,6,7,8 cases). The cases 2 and 4 correspond to an average distribution and the case 3 considers the effect of the rotorizing straightening.

BUCKLING CURVES

The effect of the residual stresses distributions on the carrying capacity of simply compression columns has been examined by means of a simulation calculation. The residual stresses patterns and the average yield points used in the buckling calculations are shown in fig. 6.

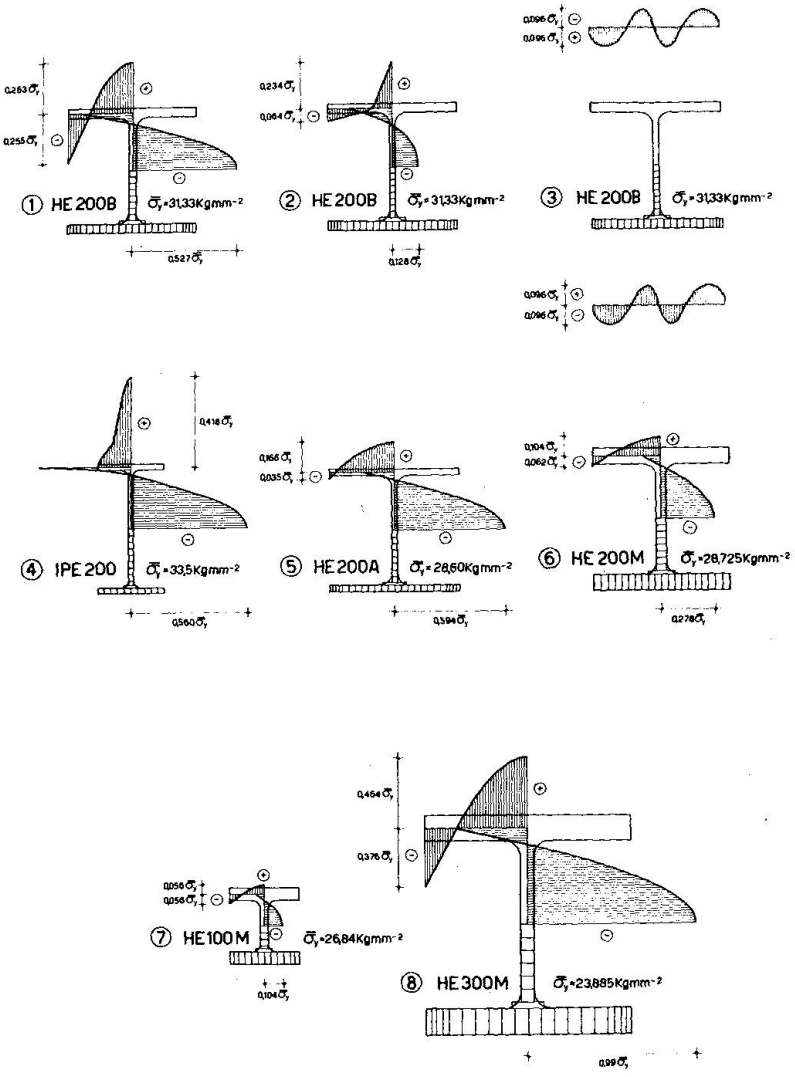


fig. 6

The numerical results have been obtained using the calculation program of the Centro Studi Costruzioni Metalliche (C.S.C.M.) of the Politecnico of Milan (10).

In order to compare the present results with the CECM-ECCS a,b,c curves the residual stresses distributions of fig. 6 have been considered together with the value $f/_1 = 1/1000$ as geometrical imperfection, whereas the yield point distribution (fig. 1) has been neglected, using just the average values $\bar{\sigma}_y$ of fig. 6. The obtained dimensionless buckling curves, have been plotted in fig. 7,8,9, refering to the strong (max) and the weak (min) axes.

Fig. 7 shows the comparison among the residual stresses structural pattern (1), the average distribution (2) and the effect of rotorizing (3) in HEB 200 shapes.

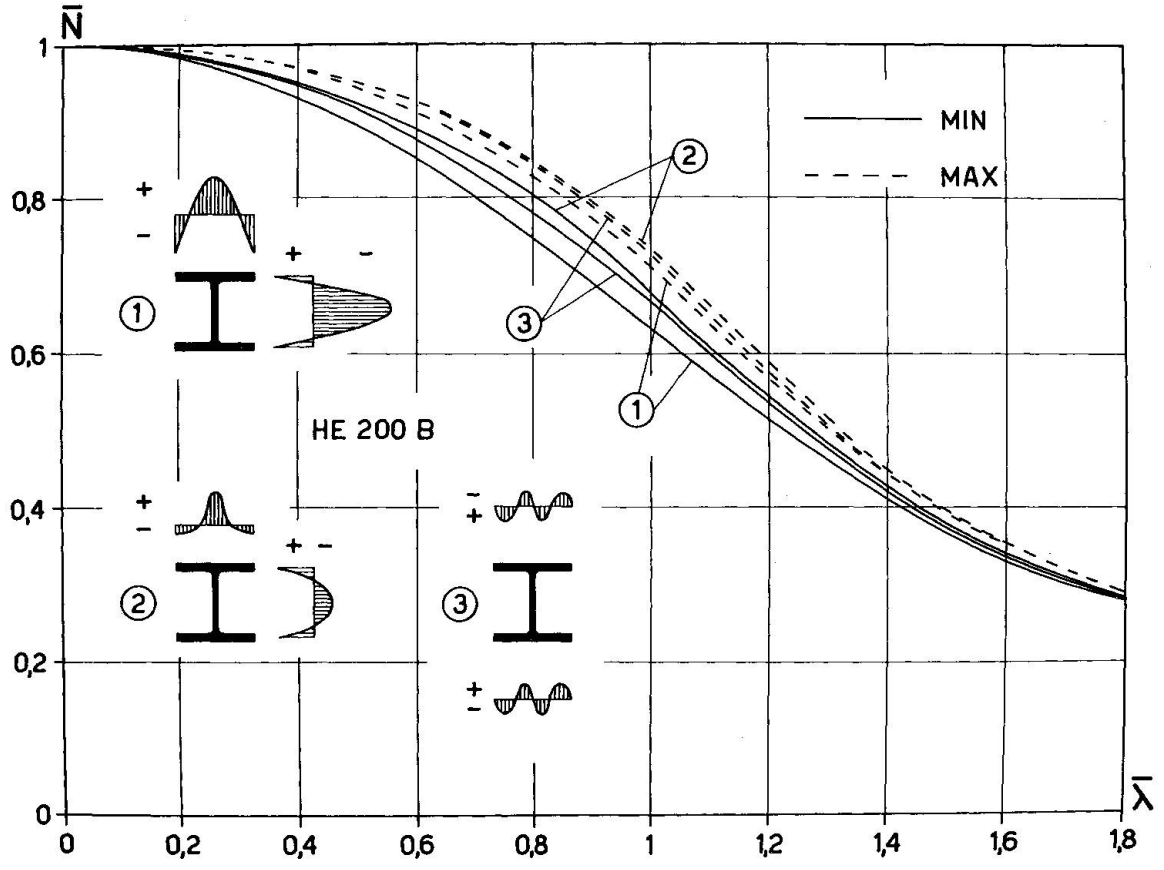


fig. 7

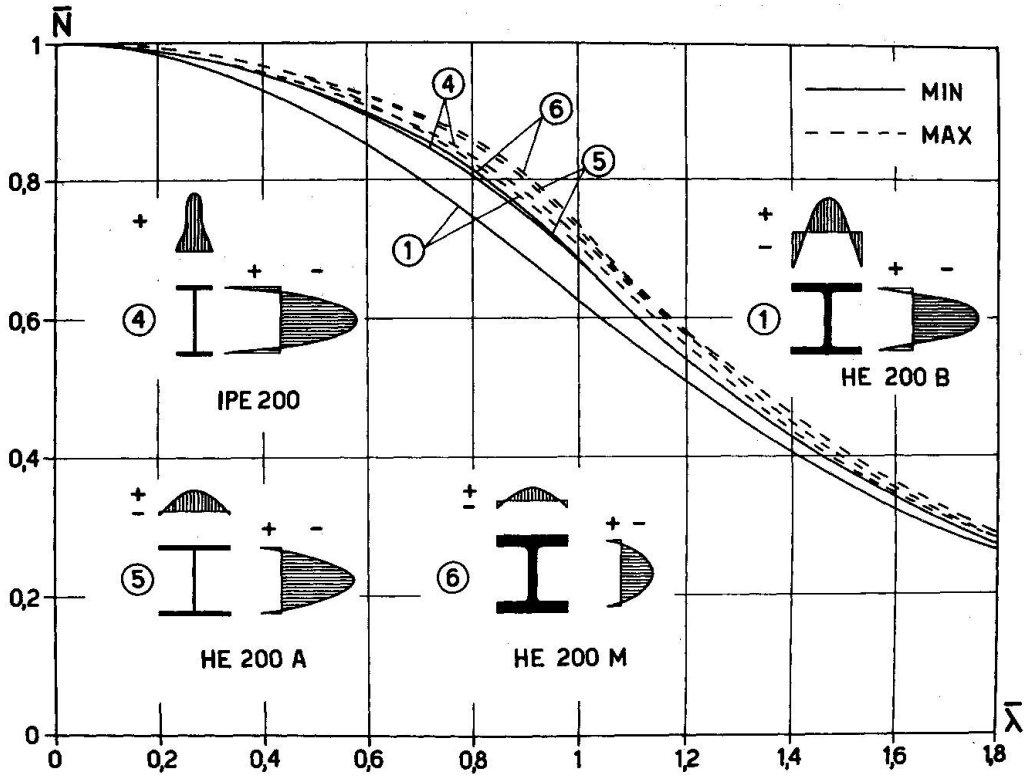


fig. 8

Different distributions of residual stresses on shapes with the same depth (HEA, HEB, HEM, IPE 200) lead to the buckling curves of fig. 8.

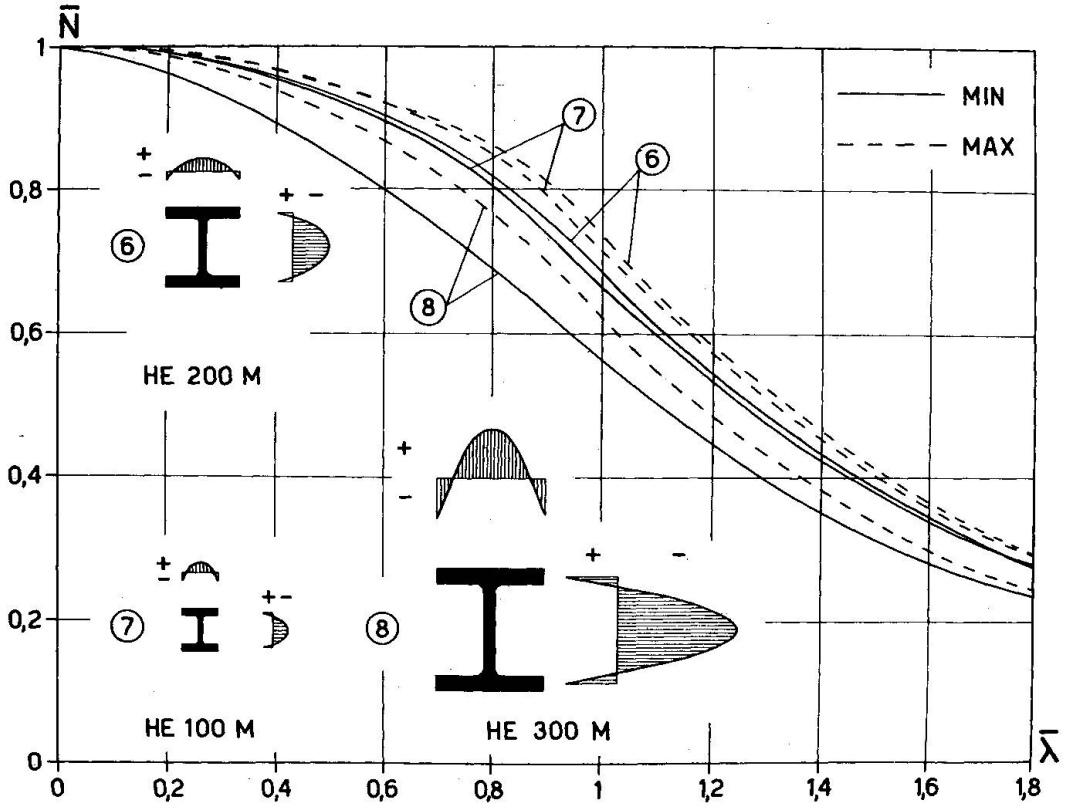


fig. 9

The distribution (1) of residual stresses in the HEB 200 represents always a lower bound for all the curves of fig. 7 and 8. The increase in depth for the same shape (HEM) makes the effect of residual stresses more important (fig. 9).

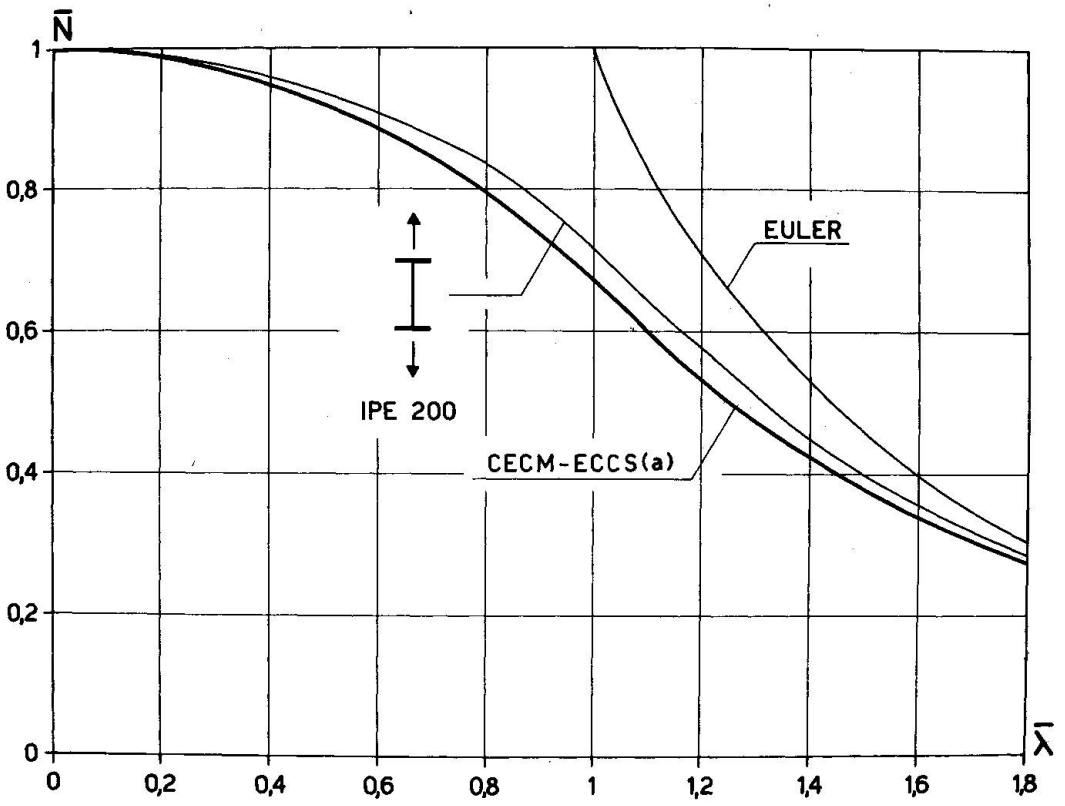


fig. 10

The obtained buckling curves have been plotted together with the CECM-ECCS a,b,c curves (fig. 10, 11, 12). The comparison between each calculated curves and the corresponding standard one shows that the CECM-ECCS curves are always more conservative than the simulation prediction based upon experimental residual stresses data. The difference may be explained, because only thermal residual stresses have been considered in the CECM-ECCS curves, without the favourable effect of rotorizing procedure, commonly used in the hot-rolled shapes manufacturing, which increases column strenght.

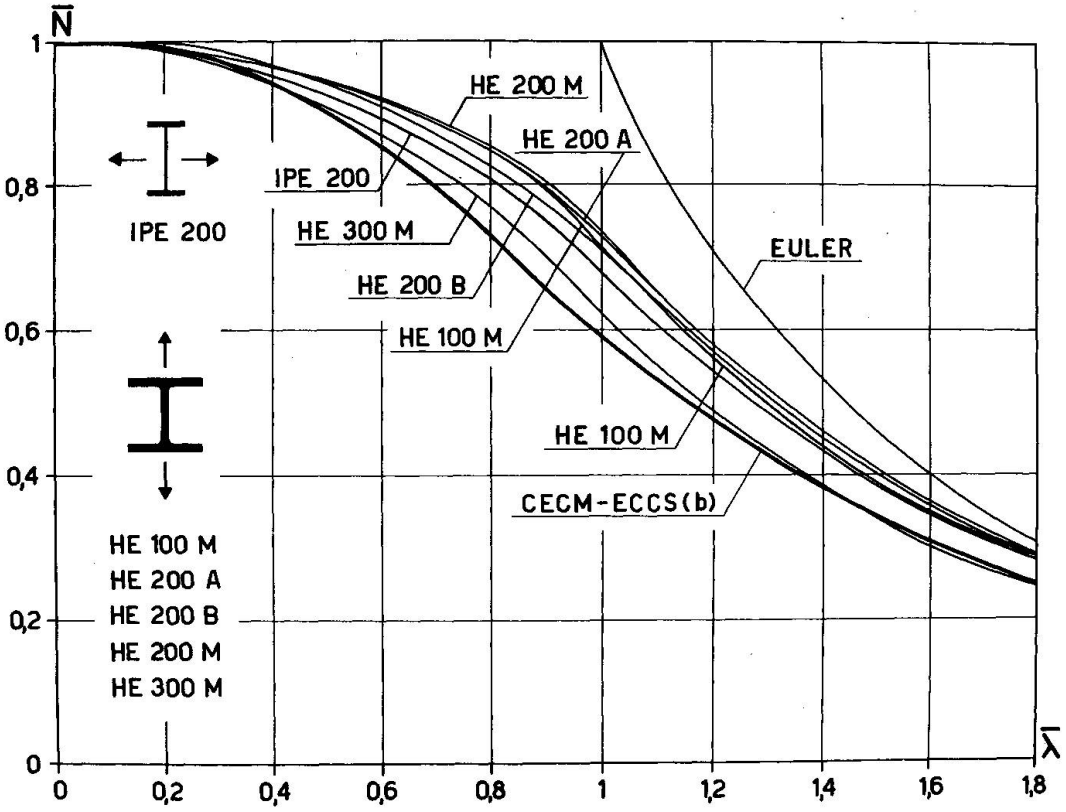

N̄
1
0,8
0,6
0,4
0,2
0
0
0,2
0,4
0,6
0,8
1
1,2
1,4
1,6
1,8
λ̄
HE 200 M
HE 200 A
IPE 200
HE 300 M
HE 200 B
HE 100 M
EULER
HE 100 M
CECM-ECCS(b)
IPE 200
HE 100 M
HE 200 A
HE 200 B
HE 200 M
HE 300 M

fig. 11

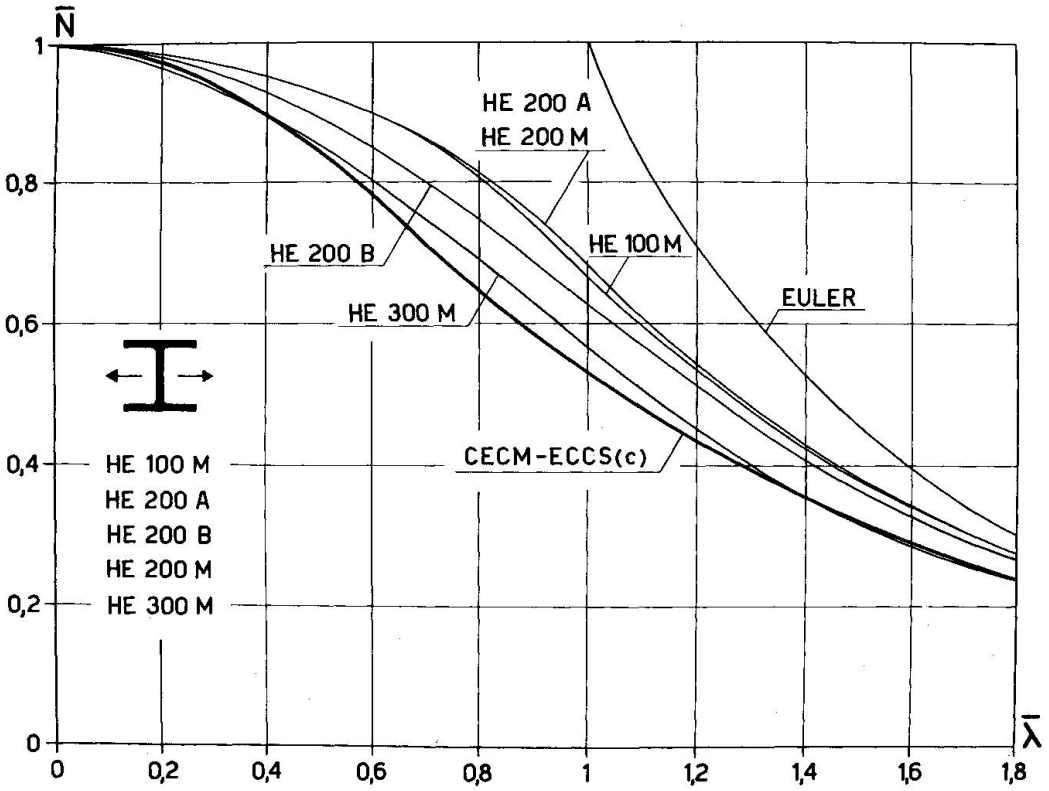

N̄
1
0,8
0,6
0,4
0,2
0
0
0,2
0,4
0,6
0,8
1
1,2
1,4
1,6
1,8
λ̄
HE 200 A
HE 200 M
HE 200 B
HE 100 M
HE 300 M
EULER
CECM-ECCS(c)
HE 100 M
HE 200 A
HE 200 B
HE 200 M
HE 300 M

fig. 12

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