5.2 Basis of the ECCS Buckling Curves

From 1960 onwards, an international experimental programme was carried out by the ECCS to study the behaviour of standard columns [2]. More than 1000 buckling tests, on various types of members (I, H, T, U, circular and square hollow sections), with different values of slenderness (between 55 and 160) were studied. A probabilistic approach, using the experimental strength, associated with a theoretical analysis, showed that it was possible to draw some curves describing column strength as a function of the reference slenderness. The imperfections which have been taken into account are: a half sine-wave geometric imperfection of magnitude equal to 1/1000 of the length of the column; and the effect of residual stresses relative to each kind of cross-section.

The European buckling curves (a, b, c or d) are shown in Figure 14. These give the value for the reduction factor χ of the resistance of the column as a function of the reference slenderness for different kinds of cross-sections (referred to different values of the imperfection factor α).

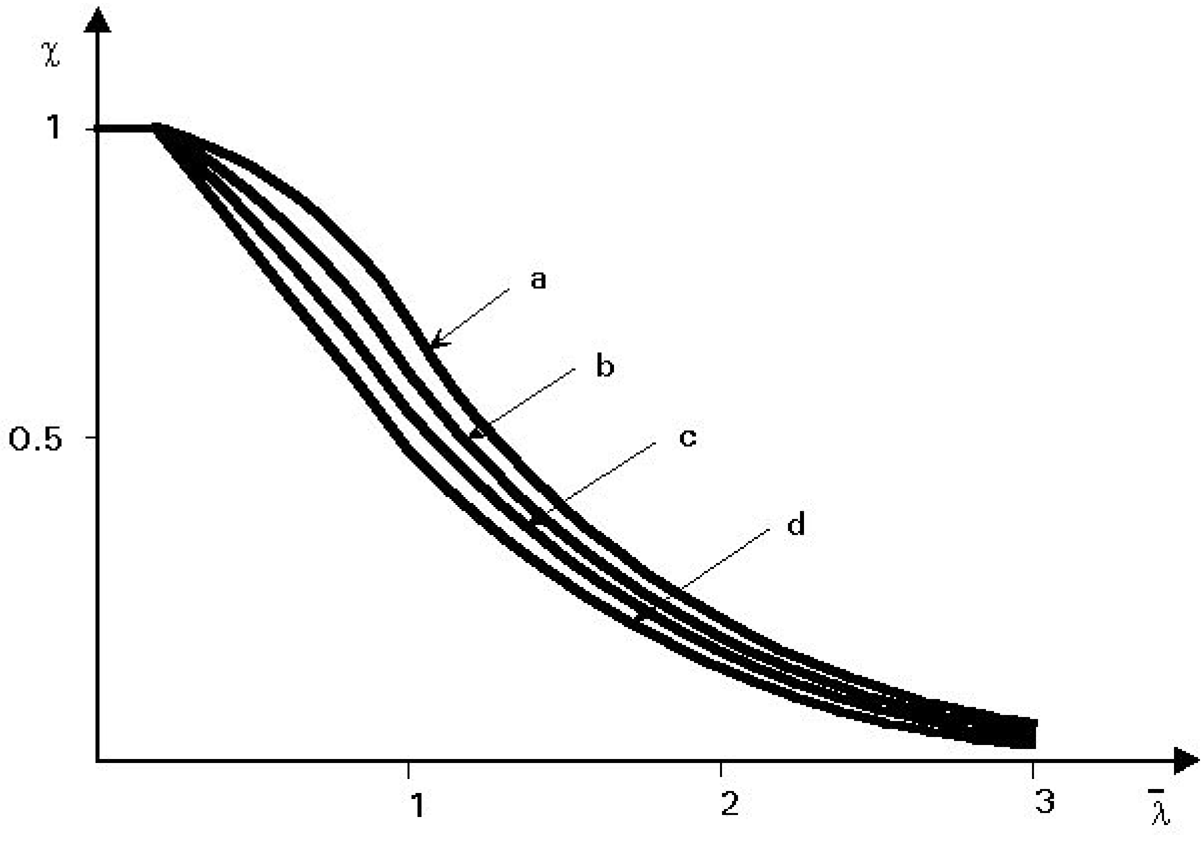

Figure 14 European buckling curves

The mathematical expression for χ is:

$$\chi = 1/ \{\phi + [\phi^2 - \bar{\lambda}^2]^{1/2}\} \leq 1 \qquad (10)$$

$$\text{where: } \phi = 0,5\ [1 + \alpha\ (\bar{\lambda} - 0,2) + \bar{\lambda}^2] \qquad (11)$$

Table 1 gives values of the reduction factor χ as a function of the reference slenderness $\bar{\lambda}$.

The imperfection factor α depends on the shape of the column cross-section considered, the direction in which buckling can occur (y axis or z axis) and the fabrication process used on the compression member (hot-rolled, welded or cold-formed); values for α, which increase with the imperfections, are given in Table 2.

Curve a represents quasi perfect shapes: hot-rolled I-sections (h/b > 1,2) with thin flanges ($t_f \leq$ 40mm) if buckling is perpendicular to the major axis; it also represents hot-rolled hollow sections.

Curve b represents shapes with medium imperfections: it defines the behaviour of most welded box-sections; of hot-rolled I-sections buckling about the minor axis; of welded I-sections with thin flanges ($t_f \leq$ 40mm) and of the rolled I-sections with medium flanges (40 < $t_f \leq$ 100mm) if buckling is about the major axis; it also concerns cold-formed hollow sections where the average strength of the member after forming is used.

Curve c represents shapes with a lot of imperfections: U, L, and T shaped sections are in this category as are thick welded box-sections; cold-formed hollow sections designed to the yield strength of the original sheet; hot-rolled H-sections (h/b ≤ 1,2 and $t_f \leq$ 100mm) buckling about the minor axis; and some welded I-sections ($t_f \leq$ 40mm buckling about the minor axis and t_f > 40mm buckling about the major axis).

Curve d represents shapes with maximum imperfections: it is to be used for hot-rolled I-sections with very thick flanges (t_f > 100mm) and thick welded I-sections (t_f > 40mm), if buckling occurs in the minor axis.

Table 4 helps the selection of the appropriate buckling curve as a function of the type of cross-section, of its dimensional limits and of the axis about which buckling can occur. For cold-formed hollow sections, f_{yb} is the tensile yield strength and f_{ya} is the average yield strength. If the cross-section in question is not one of those described, it must be classified analogously.

It is important to note that the buckling curves are established for a pin-ended, end loaded member; it is necessary carefully to evaluate the buckling lengths if the boundary conditions are different, see Lecture 7.7.

Table 1 Reduction factors

$\bar{\lambda}$	Reduction factor χ			
	Curve a	Curve b	Curve c	Curve d
0,2	1,0000	1,0000	1,0000	1,0000
0,3	0,9775	0,9641	0,9491	0,9235
0,4	0,9528	0,9261	0,8973	0,8504
0,5	0,9243	0,8842	0,8430	0,7793
0,6	0,8900	0,8371	0,7854	0,7100
0,7	0,8477	0,7837	0,7247	0,6431
0,8	0,7957	0,7245	0,6622	0,5797
0,9	0,7339	0,6612	0,5998	0,5208
1,0	0,6656	0,5970	0,5399	0,4671
1,1	0,5960	0,5352	0,4842	0,4189
1,2	0,5300	0,4781	0,4338	0,3762
1,3	0,4703	0,4269	0,3888	0,3385
1,4	0,4179	0,3817	0,3492	0,3055
1,5	0,3724	0,3422	0,3145	0,2766
1,6	0,3332	0,3079	0,2842	0,2512
1,7	0,2994	0,2781	0,2577	0,2289
1,8	0,2702	0,2521	0,2345	0,2093
1,9	0,2449	0,2294	0,2141	0,1920
2,0	0,2229	0,2095	0,1962	0,1766
2,1	0,2036	0,1920	0,1803	0,1630
2,2	0,1867	0,1765	0,1662	0,1508

2,3	0,1717	0,1628	0,1537	0,1399
2,4	0,1585	0,1506	0,1425	0,1302
2,5	0,1467	0,1397	0,1325	0,1214
2,6	0,1362	0,1299	0,1234	0,1134
2,7	0,1267	0,1211	0,1153	0,1062
2,8	0,1182	0,1132	0,1079	0,0997
2,9	0,1105	0,1060	0,1012	0,0937
3,0	0,1036	0,0994	0,0951	0,0882

Table 2 Imperfection factors

Buckling curve	a	b	c	d
Imperfection factor α	0,21	0,34	0,49	0,76