UB & UC Member Design to BS 5950-1:2000

User Notes for UBUCmember

An Excel Template for the Design of UB & UC Sections to BS5950-1:2000 by
Dr Shaiq U.R. Khan
BEng (Civil), MEng, PhD, PE, CEng, FIStructE
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Techno Consultants Ltd
www.technouk.com

Introduction

This template helps design UB & UC section members to BS5950-1:2000. The method of design is the "Simplified Method" to Clause 4.8.3.3.1.

Based on the specified effective lengths and given values of axial load, shear and moment, member design can be checked for strength adequacy and or sized by using UBUCmember.

In addition to axial load and moments in two directions, the shear load can be in the X as well as the Y-direction. The vertical shear Fy is considered as being resisted by the web and the horizontal shear Fx resisted by the two flanges.

To assist the design processes, the template also allows the following preparatory calculations:

Equivalent Uniform Moment Factor "mLT" for Lateral Torsional Buckling based on Table-18 of BS5950, and

Equivalent Uniform Moment Factor "m" for Flexural Buckling based on Table-26 of BS5950.

An interactive table gives values of member strength for over 100 sections based on steel grade, 3 effective lengths in buckling, support types and levels of axial load in the member.

Unstiffened Web bearing and buckling capacities of UB & UC Sections

In general the design method employed in this template is similar to that described in the Blue book [Ref. 2] except for some difference for Class 4 section members described later.

Method of Use

The worksheet "Home" navigates to various parts of the template via clicking of various buttons.

When designing members, data is input and results obtained via worksheet "SimpleDesign". The green shaded cells only can be selected and modified for data input.

The procedure for designing and checking a member is:
- select a UB or UC section from the drop down list;
- select the steel grade from the list (*S275, S355 or S460*);
- input appropriate values of design 2 shears, 2 moments and 1 axial force;
- input appropriate value of effective lengths, 2 for compression resistances and 1 for buckling resistance moment;
- choose whether or not the member supports are simply-supported, cantilever or continuous
- input values for the equivalent uniform moment factors.

Data Storage

Design data can be stored in worksheet "Store" for more than say 3000 members, as required. Two buttons in the header of worksheet "Store" allow the addition and deletion of data rows.

Starting from a minimum of 200 members, data rows are added and or deleted in multiples of 10 and up to 1000 rows at a time .

When familiarity has been gained, data in the worksheet "Store" can be modified directly for ease and Auto Analysis of all members. This worksheet includes columns which summarize the usage levels and status for each member. Overstressed members can be identified at a glance.

A data reference number starting from 1001 upwards is used for each member data. The data can be recalled, amended and or re-stored later for any member by the use of this reference number.

The worksheet "SimpleDesign" has buttons to allow retrieval of the stored data. Relevant buttons at the top of this worksheet can be clicked to store, retrieve, display-next or display-previous member data.

Auto Analysis and or Paper Printing of Results

A facility via worksheet "Store" provides an option to analyse and or print all members by a single click of the "Auto Analyse/Print" Button.

To use this facility, there are two rightmost columns (coloured yellow) in the worksheet "Store". One column is headed "Analyse Y?" and the other "Print Y?". An "Auto Analyse/Print" Button is also located at the top of these two columns.

Entering "X" in these two columns signifies that the member in the row needs analysing and or its results printing. Leaving the cells blank signifies that the respective member is not to be analysed and or printed.

This auto facility is useful when all or a selected few members are to be analysed and or printed after corrections to the design data e.g. changes in steel grade, effective lengths, loading, supports, etc.

These changes can be made directly in the worksheet "STORE"; this however requires a good understanding of the stored data. Caution is therefore necessary for obtaining valid results and to avoid fouling of the stored data.

Auto Analysis and or Digital Output of Results
The use of this option is similar to the previous section. Clicking of this button writes the results in the worksheet "Output" rather than print on paper.

These results in the "Output" worksheet can then be copied and or processed elsewhere for presentation and or emailing.

Member Strength Table: "Axial+Shear+Bending" Worksheet
This table displays axial, shear and bending capacities of UB, UC & RSJ sections with the following features:

1. Number of UB, UC & RSJ sections are 141 from worksheet "UBUCprop".
2. The steel grades can be S275, S355 & S460. The selection of grade is via pull-down values in a header cell. If required, steel grades for some previous periods can also be selected.
3. The colour of table cells in the first 3 left columns and 3 header cells changes to indicate the selected grade; red= S275, green= S355 & yellow= S460
4. Buckling resistance moment capacity can be Mb for normal design or Mbs for columns in simple construction. The selection of Mb or Mbs is via pull down list in a header cell.
5. Supports can be simply supported, cantilever or continuous at one or both ends. The selection is via pull down list in a header-cell. As stated in Cl 4.2.5.1, this is to avoid irreversible deformation under serviceability loads; the values of Mc are limited to 1.5 py Z generally and to 1.2 py Z in the case of simply supported beam or a cantilever.
6. The effective lengths Lx, Ly & L_{ET} affecting the member capacities can be defined to suit the design in 3 header cells at top.
7. The axial load to section axial capacity ratios can be defined to suit the design via 3 header cells at top. These ratios are:
   - Fz/Pz = Applied axial load to section axial capacity ratio. This affects the section classification & the value is in the range +1 to -1, where +ve Compression & -ve Tension
   - Fvy/Pvy = Applied shear load to shear capacity ratio in the Y-direction (range 0 to 1). Load is assumed passing through the section centroid.
   - Fvx/Pvx = Applied shear load to shear capacity ratio in the X-direction (range 0 to 1). Load is assumed shared equally between the 2 flanges.

Section Dimensions and Properties: Worksheet "UBUCprop"
There are over 140 sections in this worksheet for member design. This worksheet is protected with no password. Hence the users can change and incorporate their own properties if required.

Although included in this template, the ratios of the flange outstand to its thickness (b/T) and the web depths to its thickness (dlt) are calculated within the template itself for better accuracy.

Bearing & Buckling Capacity of UB & UC Sections
The worksheet "Web Bearing Buckling" helps calculate:
   - Pbw = Unstiffened Web Bearing Capacity Pbw to Clause 4.5.2.1
   - Px = Unstiffened Web Buckling Capacity Px to Clause 4.5.3.1
   - Pv = Shear Capacity of the Section
To calculate the above values:
   - Section size can be selected from the drop-down cell for 141 sections
   - Steel grade can be S275, S355 & S460 and is selected from drop down cell values
   - Dimension b1 & b2 and ratio Le/d can be changed in 3 green colour cells.

Equivalent Uniform Factor, mLT for Lateral Torsional Buckling
The factor m_{LT} for lateral-torsional buckling is obtained from **Table 18** (but observing **cl. 4.3.6.6**) for the pattern of major axis moments over the segment length L_{LT} governing M_b.

The worksheet "mLT" helps calculate this Factor mLT. Based on Table 18 of BS5950-1:2000, there are 7 cases of span moment variation for which this factor can be calculated.

Equivalent Uniform Moment Factor "m" for Flexural Buckling

Two factors m_x & m_y need to be defined for member design.

The factor m_x is for the major axis flexural buckling. It is obtained from **Table 26** by observing **cl. 4.8.3.3.4** for the pattern of major axis moments over the segment length L_x governing P_{cx}.

The factor m_y is for the minor axis flexural buckling. It is obtained from **Table 26** by observing **cl. 4.8.3.3.4** for the pattern of minor axis moments over the segment length L_y governing P_{cy}.

The worksheet ‰mFB+helps calculate these two factors mx and my. Based on Table 26 of BS5950-1:2000, there are 5 cases of span moment variation for calculating this factor.

Design Method for Class 4 Slender Sections

Similar to the casual use of Blue Book by designers, this template deals with the strength of Class 4 sections as follows:

Similar to the Blue Book in axial compression (i.e. Pz, Pcx, Pcy & Pc), the effective section area in conjunction with the normal design strength is used.

Similar to the Blue Book in bending (i.e. Mcx, Mcy & Mb), the gross section modulus is used in conjunction with a reduced design strength. Unlike axial compression, the effective section modulus is not used (because the method to calculate it under compression is complex and not given in the code).

Unlike the Blue Book in shear (i.e. Pvx, Pvy), gross section area is used in conjunction with a reduced design strength. This gives a conservative estimate of strength in relation to the Blue Book.

The above notes mean that the alternative method of Cl 3.6.5 is used for bending and shear but not for axial compression.

Design Strength

The member capacity and resistance values are based on the following values of design strength py:

For Grade S275,
  py= 275 for T <= 16 mm
  py= 265 for T <= 40 mm
  py= 255 for T <= 63 mm
  py= 245 for T <= 80 mm
  py= 235 for T <= 100 mm
  py= 225 for T <= 150 mm

For Grade S355,
  py= 355 for T <= 16 mm
  py= 345 for T <= 40 mm
  py= 335 for T <= 63 mm
  py= 325 for T <= 80 mm
  py= 315 for T <= 100 mm
  py= 295 for T <= 150 mm

For Grade S460,
  py= 460 for T <= 16 mm
  py= 440 for T <= 40 mm
  py= 430 for T <= 63 mm
  py= 410 for T <= 80 mm
  py= 400 for T <= 100 mm

In addition, UBUCmember also allows the use of steel stresses for some previous periods. Whereas the current grade is S275, the previous grades have been named as S275.1, S275.2, S275.3, S275.4, S275.5, S275.6 & summarised below together with the yield stresses used.

Used Yield Strengths in N/mm2 for Steels of Various Period

Period		Grade	Flange Thickness Up to					
from	to	Name	16 mm	40 mm	63 mm	80 mm	100 mm	150 mm
2000	Current	S275	275	265	255	245	235	225
1990	2000	S275.1	275	265	255	245	235	
1986	1989	S275.2	275	265				
1969	1985	S275.3	255	245				

Period		Grade	Flange Thickness Up to		
from	to	Name	16 mm	40 mm	48 mm

from	to	Name	16 mm	19 mm	40 mm
1959	1968	S275.4	250	245	230
1948	1958	S275.5	235	225	
1910	1947	S275.6	235	225	

The above stresses are based on the best available information and not an agreed & verified information in the profession.

Section Classification *(Cl. 3.5)*

Section classification is determined to **Table 11** for both flange and web. The higher classification of the two is then selected as the overall classification for a given section.

The limits for the classification of the flange are:

b/T m9ε --> class 1

m10ε --> class 2

m15ε --> class 3

> 15ε --> class 4

The limits for the classification of the web are:

d/t m80$\varepsilon/(1+r_1)$, but ⁻40ε for class 1- plastic

m 100$\varepsilon/(1+r_1)$, but ⁻40   for class 2 - compact in tension

m 100$\varepsilon/(1+1.5r_1)$, but ⁻40   for class 2 - compact in compression

m 120$\varepsilon/(1+r_2)$, but ⁻40   for class 3- semi-compact

> 120$\varepsilon/(1+r_2)$, but ⁻40   for class 4- slender

Where:

= $(275/py)^{0.5}$

r_1 = Fc/d t pyw) but >-1 and <=1

r_2 = Fc / (Ag pyw)

The overall section class is higher of the flange and the web class.

For Slender sections, all of the current UB and UC sections are never slender under pure bending.

However, some of these sections can become slender when subject to compression, due to their web becoming slender.

Tension Capacity, *Pt (Cl 4.6.1)*

The tension capacity is obtained by ignoring any missing areas due to bolt holes, given by:

$Pt = py\ Ag$

The load is assumed concentric to the section centroid. Any eccentricity that may be present needs to be accounted for by including its influence in the moments Mx and My.

No allowance is made for any reduction in area due to holt holes.

Compression Capacity, *Pt (Cl 4.6.1)*

The strength relates to the section capacity and is obtained by ignoring any missing areas due to bolt holes, given by:

$Pz = py\ Ag$ for Class 1, 2 or 3 sections

$py\ Aeff$ for Class 4 slender sections

The load is assumed concentric to the section centroid. Any eccentricity that may be present needs to be accounted for by including its influence in the moments Mx and My.

Compression Resistance, P_c *(Cl 4.7)*

The effective lengths L_x and L_y are required for buckling about the major and the minor axis. When a member is fully restrained in a plane, the effective length can be "0".

The slenderness ratio   is then determined from *cl. 4.7.2* as:

= L_E / r_x for determining P_{cx} ,

= L_E / r_y for determining P_{cy} .

The compressive strength, p_c , is determined from the formulae given in Annex *C.1* and *C.2* as follows:

pc = $p_E\ py\ /\ (\phi + (\phi^2 - p_E\ py)^{0.5}))$

where:

p_E = $\pi^2 E / \lambda^2$

ϕ = [py + $(\eta+1)p_E$] / 2

λ_o = 0.2 $(\pi^2 E/py)$

= a $(\lambda - \lambda_o)/1000$ but η ⁻ 0

a = 2.0for curve a), 3.5for curve b), 5.5for curve c) and 8.0for curve d)

The compression resistance is given by *cl. 4.7.4* as:

$P_c = A_g \; p_c$ for Class 1, 2 or 3

      $A_{eff} \; p_{cs}$ for Class 4

where p_{cs} is the value of p_c for a reduced slenderness $= \lambda \; (A_{eff}/A_g)^{0.5}$

For welded I or H sections pc is obtained by using a py value 20 N/mm2 below that for rolled sections. This reduced py however applies only when calculating pc using the above formulae in Annex C.1 - see Cl 4.7.5

Buckling Resistance Moment, M_b *(Cl. 4.3)*

The effective length L_E is required for buckling about major axis and minor axis. When a member is fully restrained laterally, the effective length can be "0".

The slenderness ratio   is then determined from *cl. 4.7.2* as: $= L_E / r_y$.

The equivalent slenderness $_{LT}$ is given in *cl. 4.3.6.7* as: $_{LT} = u \; v \;$ Sqrt(w)

where

    u = buckling parameter of the section

    $v = 1 / [1 + 0.05 (\lambda /x)^2]^{0.25}$

    x = torsional index of the section

    $\beta_w = 1$ (for Class 1 or 2), S_{xeff}/S_x (for Class 3), $Z_{x,eff}/S_x$ (for Class 4)

The bending strength, p_b, is determined from the formulae given in Annex *B.2* as follows:

pb = p_E py / (ϕ_{LT} + (ϕ_{LT}^2 - p_E py)$^{0.5}$))

where:

    $p_E = \pi^2 E / \lambda_{LT}^2$

    $\phi_{LT} = [py + (\eta_{LT}+1)p_E] / 2$

    $_{LT} = \alpha_{LT} (\lambda_{LT} - \lambda_{L0})/1000$ but $_{LT} ^- 0$

    $\lambda_{Lo} = 0.4 (\pi^2 E/py)$

    $\alpha_{LT} = 7.0$

The buckling resistance moment is obtained from *cl. 4.3.6.4* as:

$M_b = p_b \; S_x$ for Class 1 or 2

     $p_b \; S_{xeff}$ for Class 3

     $p_{br} \; Zx$ for Class 4

Shear Capacity, P_v *(Cl. 4.2.3)*

The shear capacity is given by:

$P_v = 0.6 {*} p_y {*} A_v$ for Class 1, 3 and 3 sections, and

     $0.6 {*} p_{yr} {*} A_v$ for Class 4 sections (using p_{yr} as per Cl 3.6.5).

For P_{vy}, the shear area A_v is given by *cl. 4.2.3.a)* : $A_v = tD$

For P_{vx}, the shear area A_v is given by *cl. 4.2.3.h)* : $A_v = 0.9 \, A_o$,

where $A_o = 2T(B - t)$.

This equation for Ao ensures that common portion of the section in the flange and the web is not included twice in resisting shear.

When calculating the moment capacity Mc, it is necessary to establish whether the section is in 'low shear' (F_v m0.6$ {*} P_v$) or 'high shear' ($F_v > 0.6 {*} P_v$). When the section is in high shear, the moment capacity Mc is reduced as per Cl 4.2.5.

Moment Capacity, M_c *(Cl. 4.2.5)*

As stated in *cl. 4.2.5.1* , to avoid irreversible deformation under serviceability loads, the value of M_c is limited to:1.2 $p_y \; Z$ in case of a simply supported beam or a cantilever, or   1.5 py Z in any other case.

In case of 'low shear', the moment capacity using *cl. 4.2.5.2* is given by:

$M_c = p_y \; S$ for Class 1 or 2

     $p_y \; Seff$ for Class 3

     $p_{yr} \; Z$ for Class 4

In case of 'high shear', the moment capacity using *cl. 4.2.5.3* is given by:

$M_c = p_y \, (S - \rho S_v)$ for Class 1 or 2

$\quad\quad p_y \, (Seff - \rho S_v /1.5)$ for Class 3

$\quad\quad p_{yr} \, (Z - \rho S_v /1.5)$ for Class 4

where:

S_v = plastic modulus of the shear area A_v defined in the notes on the "*Shear capacity*"

$\rho = [2 \, (F_v /P_v) - 1]^2$

When the section is Class 4 slender due to the web, the moment capacities are calculated using a reduced design strength pyr and the gross section properties, instead of py Zeff (Cl 3.6.5).

It is worth noting that for rolled UB/UC sections the ratio d/t never exceeds 70ε *and hence* there is no need to check for shear buckling.

Cross-Section Capacity Check
For members subject to compression plus bending, the interaction check is to *cl. 4.8.3.2* .

For members subject to tension plus bending, the interaction check is to c*l. 4.8.2.2* .

Member Buckling Resistance Check
For members subject to compression plus bending, the interaction check is to *cl. 4.8.3.3.1 using the 'simplified method'* .

Effective Section Properties: Worksheet UBUCprop
When designing class 3 semi-compact and class 4 slender cross-sections to BS 5950-1: 2000, effective section properties are required. These properties depend upon the grade of steel used and the level of axial compression.

The use of this worksheet is self explanatory. It gives effective section properties for steel grades S275, S355 & S460 and the level of axial load in relation to section capacity. In the top header rows of this worksheet, the steel grade can be selected and the axial load Fz/Pz ratios defined.
.
The range of applied axial load to section axial capacity Fz/Pz ratio is +1 to -1. The values are +ve for Compression & -ve for Tension.

Effective Plastic Modulus of Class 3 Semi-compact Section
For class 3 semi-compact I or H sections with equal flanges, the effective plastic moduli Sxeff and Syeff about the major and minor axes is obtained by using equations in Cl 3.5.6.2.

Effective Area of Class 4 Slender Sections
This area applies to Class 4 slender sections only. When web controls the section classification, the effective area is:

$\quad\quad$ Aeff $=$ Ag - t (d - 40 t ε) for both rolled and welded sections

When flanges controls the section classification, the effective area is:

$\quad\quad$ Aeff $=$ Ag - T (B - 60 T ε) for rolled sections, and

$\quad\quad$ Aeff $=$ Ag - T (B - 52 T ε) for welded sections.

Effective Elastic Modulus of Class 4 Slender Sections
Under axial load, the code gives no method for calculating this value of Zeff. Hence the alternative method given Cl 3.6.5 is used, which obviates the need to calculate this Zeff value.

In calculating the Class 4 section resistance in bending, while normal elastic modulus Z is used the design strength is reduced.

The value of the reduced design strength pyr is obtained from:

$\quad\quad p_{yr} = (\beta_3 / \beta)^2 \, p_y$

Notations
The symbols used are generally the same as those in BS 5950-1: 2000. They are as listed in the worksheet "*Notations*".

References

1) *BS 5950 Part 1: 2000 - Code of practice for design - Rolled and welded sections*

2) Steelwork Design Guide to BS5950-1: 2000, Volume 1, Section Properties, 6th Edition, The Steel Construction Institute, BCSA, 2001