VERIFICATION OF AREAS OF I.S. ROLLED STEEL SECTIONS

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Abstract

General Steel Structures are designed using standard steel sections. The design is governed by the Code IS 800-2007, and the standard steel sections are chosen from SP: 6(1)-1964.The standard steel sections regularly used in construction are, I, Channel, Tee and Angle (Equal & Unequal) sections, i.e., overall 252 sections. SP: 6(1)-1964 gives the sectional properties of all these 252 standard sections, including the cross sectional areas, for the use of designers, to select the most stable and economical section to satisfy the loading conditions of the structure. An economical section is one which has the least cross sectional area and hence, least weight. In SP: 6(1)-1964, the cross sectional areas are given in cm^2 to an accuracy of two decimal places. In this paper, the accuracy of the areas of all these sections, except ISHB sections (all IS Heavy Beams) and ISWB 600 @ 145.1 kg/m, i.e., totally 234 sections, are verified in mm^2 to an accuracy of two decimal places. The results show differences in values of areas for eight Tee-sections only, which have been tabulated. Cross sectional areas of all other 226 sections perfectly match with the values given in SP: 6(1)-1964.

Index Terms: *IS 800-2007, SP: 6(1)-1964, Cross Sectional Areas*

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1. INTRODUCTION

As per IS 800- 2007 [1], steel structures are to be designed by Limit State Method, where the designer has to select the most stable and economical section to satisfy the loading conditions of the structure. An economical section is the one which has the least cross sectional area and hence, least weight. Also, important properties like, Moment of inertia, Radius of Gyration, Section Modulus, Plastic Modulus, etc. depend upon the cross sectional area. Indian rolled steel sections consist of sloping flanges, fillets at junctions and rounded ends. These geometrical complexities have been incorporated in the calculation of the cross sectional areas in this paper. To be more specific, the Indian Standard Rolled Steel I, Channel and Tee - Sections can be seen as having two main components, namely flanges and webs. The web is usually a straight portion, with parallel edges, whose area and other properties can be easily determined. However, the flanges are in the form of cantilevering outstands having two straight non parallel edges with one end attached to the web, and the other free end rounded off by a circular arc of definite radius, r_2 [2]. Also, at the junction of the flange outstand and web, a circular fillet of definite radius, r_1 [2], is provided. The calculation of the area and other properties of this flange outstand portion is not simple due to these geometrical complexities. Similarly, the Indian Standard Angle Sections, both Equal and Unequal Sections, are made of two legs, each perpendicular to the other with a circular fillet of definite radius, r_1 [2], at their junction. The two long edges of each leg are parallel, and the free end is rounded off by a circular arc of definite radius, r_2 [2].

The cross sectional properties given by the SP: 6(1)-1964 [2] are used by the structural designers across the country (India). The nation has switched to the SI units, but the units used in the SP: 6(1) -1964 [2] still exist in cm^2, cm^3 and cm^4, for some important properties like, Moment of inertia, Area, Section Modulus, etc. In this paper, the areas of the above mentioned standard sections are calculated in mm2, to an accuracy of two decimal places, considering the geometry described above, and are verified with the areas already in use, since 1964, vide SP : 6(1) -1964 [2]. The results show differences in values of areas for eight Tee-sections only and these values have been tabulated.

2. METHOD OF CALCULATION

Fig. 1 represents typical geometry of the flange with non-parallel sides with respect to I, Channel and Tee sections. For I, Channel and Tee sections, the web is treated as a rectangular area, with one side as the thickness of web and the other side as the full depth of the section. The flange outstand is treated as made of three components, - (i) Trapezoidal area ABCD (ii) Circular Spandrel (Fillet) area, ECF, at the junction with web (iii) Negative Circular Spandrel area ABG, at the free end. The area of a section is the sum of the areas of the web and four flanges outstands for I sections or two flanges outstands for Channel/Tee sections.

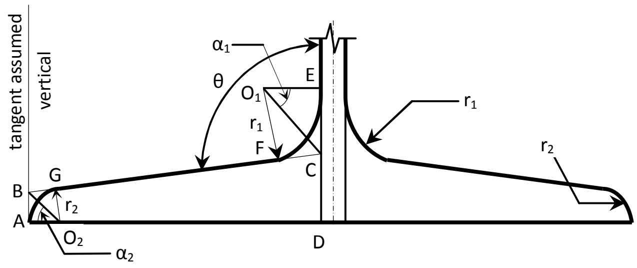

Fig.1 Flange Geometry of I, C & T Sections

The calculations of area of flange outstand is as follows:
Area of the trapezium ABCD is given by:

$AD \times ((AB + CD) / 2)$ .... (1)

Area of Circular Spandrel (Fillet) ECF is given by:

$r_1^2 \sin\alpha_1 (\cos\alpha_1 + \sin\alpha_1 \tan\alpha_1) - \alpha_1 r_1^2$ .... (2)

Area of Negative Spandrel ABG is given by:

$r_2^2 \sin\alpha_2 (\cos\alpha_2 + \sin\alpha_2 \tan\alpha_2) - \alpha_2 r_2^2$ .... (3)

Area of Cantilevering Flange outstand is given by,

AGFECDA = (1) + (2) – (3)

2.1 Typical calculation for ISWB 600 @ 133.7 kg/m:

As per SP: 6(1) -1964 [2];

Area = 170.38 cm^2; Depth = 600 mm;
Width of flange = 250 mm; Thickness of flange = 21.3 mm
Thickness of web = 11.2 mm; r_1 = 17 mm, r_2 = 8.5 mm and $\theta = 96^o$;

Therefore, $\alpha_1 = (180 - 96) / 2 = 42^o$ = 0.73308 Rad,
$\alpha_2 = (180 - 96) / 2 = 42^o$ = 0.73308 Rad,
Area of web = 600 x 11.2 = 6720.0000 mm^2

For trapezium,
AB = 15.02528 mm; CD = 27.57472 mm; AD = 119.4 mm
Therefore, Area of the trapezium = 2543.2200 mm^2
Area of Circular Spandrel (Fillet) ECF = 48.3687 mm^2
Area of Negative Spandrel ABG = 12.09218 mm^2

Area of flange outstand = 2543.2200 + 48.3687 – 12.09218
= 2579.49652 mm^2
Therefore, area of I section = 6720.00 + (4 x 2579.49652)
= 17037.98608 mm^2

Therefore, area in cm^2 = 170.38 cm^2 (correct to two decimal places), the value exactly matches with the value given in SP: 6(1) -1964 [2].

Fig. 2 represents typical geometry of the flange with parallel sides with respect to Equal and Unequal Angle sections. For Equal and Unequal Angle sections, the area is treated as made of (i) Two rectangular legs of given thickness, one leg with full length of leg and the other leg length reduced by the thickness value (ii) Circular Spandrel (Fillet) area, at the junction of the two legs (iii) & (iv) Negative Circular Spandrel areas, at both the free ends, which are equal. The area of an angle section is given by (i) + (ii) - (iii) – (iv).

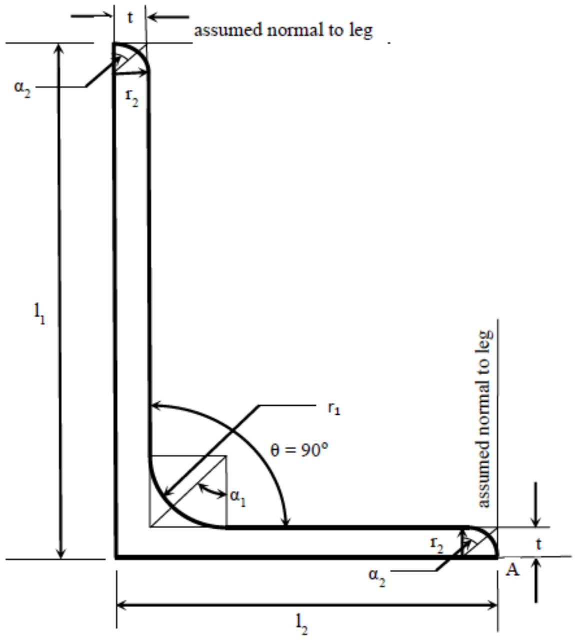

Fig.2 Geometry of Angle

The calculations are as follows:
Area of the two rectangular legs is given by:

$(l_1 + l_2 - t) \times t$ ...... (1)

Area of Circular Spandrel (Fillet) ECF is given by:

$r_1^2 \sin\alpha_1 (\cos\alpha_1 + \sin\alpha_1 \tan\alpha_1) - \alpha_1 r_1^2$ ...... (2)

Area of Negative Circular Spandrel, at both free ends:

$2 \times (r_2^2 \sin\alpha_2 (\cos\alpha_2 + \sin\alpha_2 \tan\alpha_2) - \alpha_2 r_2^2)$ ...... (3) & (4)

2.2 Typical calculation for ISA 200150 @ 46.9 kg/m:

As per SP: 6(1) -1964 [2];
Thickness = 18 mm; Area = 59.76 cm^2;
r_1 = 13.5 mm, r_2 = 9.5 mm and $\theta = 90^o$;

Therefore, α_1 = (180 – 90) / 2 = 45° = 0.785398 Rad,
α_2 = (180 – 90) / 2 = 45° = 0.785398 Rad,
Area of legs = (200+ 150 – 18) x 18 = 5976.0000 mm^2
Area of Circular Spandrel (Fillet) ECF = 39.11118 mm^2

The two negative spandrel areas, one at each free end,
i.e., Twice the Area of Negative Spandrel
ABG = 19.36782 mm^2

Therefore, area of Angle section = 5976.0000 + 39.11118 – 19.36782
= 5976.375553

Therefore area in cm^2 = 59.76 cm^2 (correct to two decimal places), the value exactly matches with the value given in SP: 6(1) -1964 [2].

3. RESULTS AND DISCUSSION

The SP: 6(1) -1964 [2] gives details of 65 – I sections, 27 channel sections, 72 equal angle sections, 65 unequal angle sections and 23 – T sections. i.e., overall 252 sections. Out of these, areas of 234 sections have been calculated in the present paper. For the remaining 18 sections, calculations differ because of manufacturing process and hence the results of these sections will be taken for separate publication. As per the methodology used in the calculation of areas of these sections it is found that for 226 sections the difference in area is less than 0.5 mm^2. Hence for these 226 sections, when the area is converted to cm^2 with two decimal places, they perfectly match with the areas given in SP: 6(1) -1964 [2]. The remaining 8 sections are only T sections. The difference in area found by this methodology for these 8 T- sections is greater than 0.5 mm^2 and the range of difference is 0.88 to 13.01 mm^2, the range of difference in percentage being 0.15 to 0.78. Excel software has been used for the above calculations and details are available in reference [3].

The tangent at A in fig. 1 and fig. 2, assumed to be vertical is true for all sections except few sections which have smaller flange thickness, such that the centre of curvature lies out of the flange. Even with such thinner flanges, the error in the calculation of area is found to affect the overall area in mm^2 at the second or third decimal place, and as such has been neglected.

Table 1

I.S. Section	Given Area (cm^2)	Calculated Area (mm^2)	Calculated Area (cm^2)	Difference (cm^2)	Difference (mm^2)	Percentage Difference (%)
ISNT 20 @ 0.9 kg/m	*1.13*	113.88	*1.14*	*0.01*	*0.88*	+0.78
ISNT 30 @ 1.4 kg/m	*1.75*	176.25	*1.76*	*0.01*	*1.25*	+0.71
ISNT 40 @ 3.5 kg/m	*4.48*	449.87	*4.50*	*0.02*	*1.87*	+0.42
ISNT 50 @ 4.5 kg/m	*5.70*	572.24	*5.72*	*0.02*	*2.24*	+0.39
ISNT 60 @ 5.4 kg/m	*6.90*	693.07	*6.93*	*0.03*	*3.07*	+0.45
ISNT 80 @ 9.6 kg/m	*12.25*	1229.91	*12.30*	*0.05*	*4.91*	+0.40
ISNT 100 @ 15.0 kg/m	*19.10*	1918.54	*19.19*	*0.09*	*8.54*	+0.45
ISNT 150 @ 22.8 kg/m	*29.08*	2921.01	*29.21*	*0.13*	*13.01*	+0.45

CONCLUSIONS

The areas of 234 out of 252 standard steel sections namely I, Channel, Tee, and Equal & Unequal Angle Sections have been calculated and verified to an accuracy of two decimal places in mm^2. It has been observed that 8 Tee sections only have slightly different areas than mentioned in the SP: 6(1)-1964, by the methodology used. This may lead to change in values of parameters like Moment of Inertia, Radius of Gyration, Section Modulus etc., which are dependent on areas or component areas, for these sections. These results may be of interest for the calculation of the other dependent parameters.

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BIOGRAPHIES

Prof. K. V. Pramod completed BE Civil and M.Tech in Industrial Structures both from KREC Surathkal (present NIT, Karnataka). He is serving as Professor in Civil Department at SDMCET, Dharwad. He handles subjects related to Steel Design at both UG and PG levels.

Dr. Gururaj A. Kulkarni obtained his PhD from Indian Institute of Science in the faculty of Science in 2011. Presently he is serving the Dept. of Physics @ SDMCET, Dharwad as an Associate Professor. He is interested in solving research problems related to Physics and its applications.