

# Chapter 3

## CHS vs. Various Cross Sections

It has been established that there exists a need to investigate other alternatives as structural members for use in high voltage power line towers in South Africa. The need for an alternative member cross-section is especially required in tower leg members seeing that they are subjected to enormous loads in double circuit power lines. The use of conventional angular members in the application of 765 kV double circuit towers has reached its load carrying limit.

Although other configurations of angular members exist, e.g. cruciform or boxed configuration, it will be demonstrated in this chapter that circular hollow section (CHS) members have better mechanical properties e.g. structural efficiency, weight advantage and lower wind resistance compared with the other structural cross-sections available in the industry (*Southern African Structural Hollow Sections Handbook* 1996).

### 3.1 Structural efficiency

The even distribution of the member material about the centroid of the cross section is the reason for the good performance of circular hollow section members. The specific distribution of material around the center of gravity results in a radius of gyration ( $r$ ), moment of inertia ( $I_{xx}$ ) and section modulus ( $Z$ ) which is constant for all principal axis (*Southern African Structural Hollow Sections Handbook* 1996) of CHS members. See figure 3.1 below.

Thus, in order to illustrate the competitive advantage that the even distribution of mass holds, a table is constructed with various structural shapes

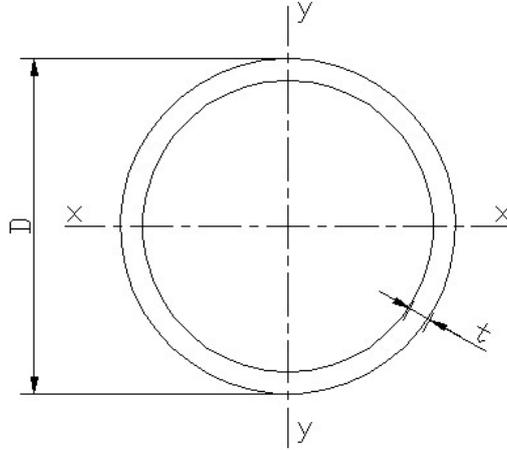


Figure 3.1: Typical details of a CHS cross-section(*The teal book - Structural hollow sections in South Africa 2010*).

that may be used as compression members. The table highlights the difference in mass ratio for three instances of critical load ( $C_r$ ) and effective length ( $KL$ ) (*Southern African Structural Hollow Sections Handbook 1996*) (Table 1.1: Relative masses of struts). The results are represented here as figure 3.2.

For each instance of effective length and critical load listed in the table, the mass ratio of the hollow sections is 1.0. For a similar load and length, a conventional angular member will weigh 2.3 more than the hollow section member. From figure 3.2, it can be seen that circular hollow section members has a definite weight advantage in terms of mass reduction.

Considering the buckling equation (equation 3.1), it can be seen that the moment of inertia ( $I$ ) is the only variable that can be used to evaluate the performance of any cross section for a constant load and constant buckling length.

$$P_{cr} = \frac{\pi^2 EI}{(KL)^2} \quad (3.1)$$

Thus, in order to show the structural advantage of CHS members of angular members, the ratio of  $I_{CHS}/I_{ANG}$  was calculated.

The first approach (Appendix D) was to assume that both members have

$C_r = 140 \text{ kN}$ $KL = 4,0 \text{ m}$			$C_r = 380 \text{ kN}$ $KL = 4,0 \text{ m}$			$C_r = 120 \text{ kN}$ $KL = 6,0 \text{ m}$		
Section (mm)	KL/r	Mass ratio	Section (mm)	KL/r	Mass ratio	Section (mm)	KL/r	Mass ratio
○ 114	102	1,0	165	70	1,0	127	138	1,0
□ 100 x 100	102	1,0	140 x 140	73	1,0	120 x 120	127	0,9
└ 120 x 120	170	2,3	150 x 150	137	2,5	150 x 150	202	1,9
┌ 90 x 65	143	1,5	125 x 75	129	1,5	100 x 75	191	1,8
⊕ 80 x 80	130	1,5	100 x 100	104	1,5	90 x 90	173	1,4
┆ 200 x 100	179	2,3	254 x 146	119	2,0	203 x 133	194	2,1

Notes:  $C_r$  = factored compressive resistance  
 KL = effective length  
 Material: Grade 300W steel  
 Mass ratio = relative mass/m of various sections  
 Mass ratios of compound angles exclude battens

Figure 3.2: Relative masses of axially loaded struts (*Southern African Structural Hollow Sections Handbook 1996*).

the same weight per meter, which would allow equivalent cross-sectional areas ( $A_{CHS} = A_{ANG}$ ). From this, the radius (R) of the CHS may be written in terms of the leg length (a) of the angular member. Several assumptions were made in the calculation; firstly, the equations for the moments of inertia were expanded and the higher- order terms were discarded. This would result in a ratio with a minimum value. The second assumption is that 't' is a lot smaller than 'a'. This calculation shows that the CHS member is 1.22 times stronger, compared with the conventional angular cross section.

Secondly, structural members should be at least class 3 members (structural use of steel Part 1:Limit-state design of hot-rolled steelwork (2005)). Thus, in order to accommodate the national code requirements for class 3 members, the thickness (t) is replaced by the corresponding  $D/t$  and  $a/t$  limits. This may be seen in appendix E. Although the equations for the moment of inertia are still used in their simplified format, the assumption of  $t \ll a$  is no longer used, seeing that all variables of (t) will be replaced by the requirements for class 3 sections. The strength of CHS members is now 11.7

times that of angular members.

Although the analytical results are not exact, owing to several assumptions and simplifications that were made, the end result still proves that there is merit in considering the use of circular- hollow sections in power-line towers. A conclusion that may be drawn from the results is that CHS members with equivalent weight and strength can span over longer lengths. This means less secondary (redundant) members, that in turn reduce the overall weight of the structure; and fewer members to fabricate and construct. Off- course, practical implications, such as standardising of members and connection requirements, will also have an effect on the final member strength and weight.

### 3.2 Reduced painting area

A comparison was conducted on paint areas for various structural members with the same structural capacity. The results prove that a sealed tube has the lowest paint area compared with the other configurations (*Southern African Structural Hollow Sections Handbook* 1996) (see figure 3.3) The table in figure 3.3 compares the external paint area of members with the same relative compressive resistance ( $C_r = 150 \text{ kN}$ ,  $KL = 4.0 \text{ m}$ ). It may be seen in the table that CHS members will have a 31% smaller painting area (external) compared with conventional angle members.

	Section (mm)	Area (m <sup>2</sup> )	Area ratio
○	114	0,36	1,00
□	100 x 100	0,39	1,08
└	120 x 120	0,47	1,31
└┘	90 x 65	0,60	1,67
┼	80 x 80	0,62	1,72
I	200 x 100	0,77	2,14

Figure 3.3: Paint area of various sections, per meter (*Southern African Structural Hollow Sections Handbook* 1996).

The outer smooth, curved surface of tubes also results in better corrosion

protection against weather elements seeing that there are fewer corners and cavities for moisture build-up (*Southern African Structural Hollow Sections Handbook* 1996, *Hot Dip Galvanizing: A Practical Reference for Designers, Specifiers, Engineers, Consultants, Manufacturers and Users* 1989).

Not only does the curved external surface provide good weather protection, but it is also architecturally appealing.

The disadvantage of using CHS in power line towers is that the towers must also be galvanized internally in order to avoid the risk of material decay on the inner surface that will over time reduce the ultimate resistance of the member without enabling visible inspection by maintenance staff. This increases the area that must be coated compared with open sections. Additionally, special care is required for galvanizing circular hollow sections which could lead to additional cost.

### 3.3 Economics of structural hollow sections

Although structural efficiency and torsional strength are definite advantages when it comes to designing structural members, it is important to mention the disadvantages of using circular hollow sections.

Firstly, the cost per ton of hollow sections compared with hot rolled sections is higher. The reason is that the manufacturing of a circular hollow sections comprises of a number of stages compared with a single stage for open sections.

The process involved in manufacturing a CHS is to form a flat coil into the desired diameter and then to seam weld it with resistance welding. Additionally, to form a square or rectangular section, the circular shape has to be further rolled into the desired shape (*Southern African Structural Hollow Sections Handbook* 1996).

Secondly, the long, smooth, slender and unsupported structural members may seem very attractive in many different building structures but they prove challenging in power line towers when it comes to erecting the towers. This is as a direct result of being required to climb the tower in the construction and stringing phase.

Special climbing features will therefore have to be implemented in order to facilitate CHS towers.

### 3.4 Tubular profiles and telecommunication structures

Smith (2007) performed a comparative study with conventional angular members and tubular members on telecommunication towers. In order to establish a relevant comparison between angular profiles and tubular profiles, the following design parameters were used:

- wind load
- ice load; and
- buckling capacity

The following conclusions were made by Nielsen & Stottrup-Andersen (2006): 1) Wind resistance is larger for square tower cross-sections than for triangular tower cross-sections. 2) For reasonable solidity ratios (effective area/ total area of tower panel), it may be seen that the drag coefficient decreases when the solidity ratio increases (see figure 3.4). Wind resistance of flat-sided profiles is frequently 50% higher than for tubes.

The ice build-up on structures can dramatically influence the vertical load and will increase the projected area of the tower. The build-up of ice is dependent on the tower member. It was found that more ice build-up is found on angular members. See figure 3.5 (Nielsen & Stottrup-Andersen 2006).

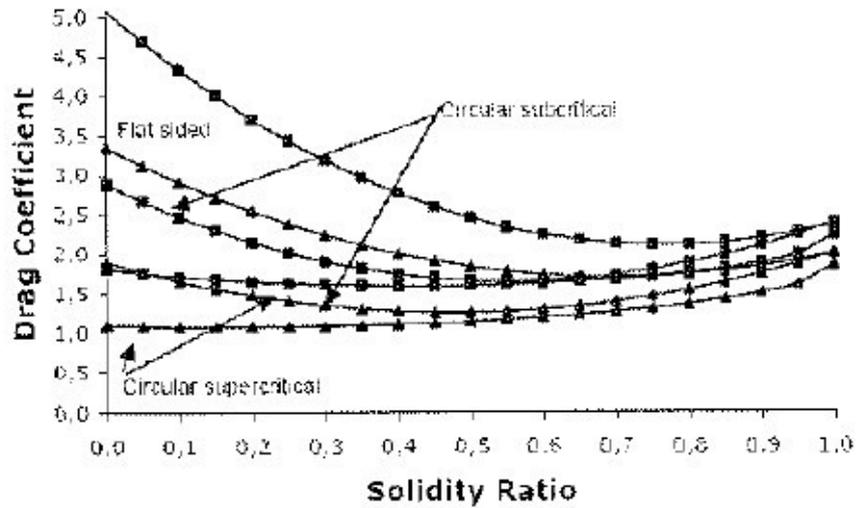


Figure 3.4: Drag coefficients for lattice triangular and square cross sections (Nielsen & Stottrup-Andersen 2006).

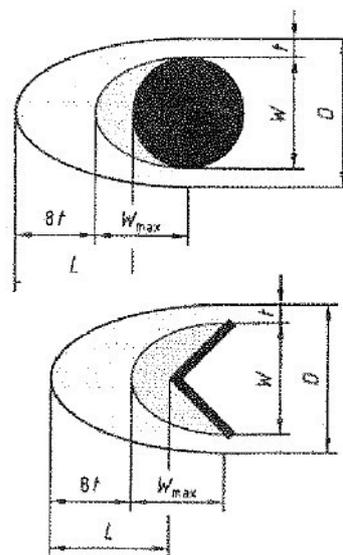


Figure 3.5: Ice buildup model for rime on circular and angular profiles (ISO 12492 2001) (Nielsen & Stottrup-Andersen 2006).

Furthermore, it is shown that hot-rolled circular profiles produce 20% higher buckling capacity compared with angular members based on non-dimensional slenderness ( $L/r$ ) (Nielsen & Stottrup-Andersen 2006); meanwhile, the eccentric connections found with angular members reduces the buckling capacity of tower members.

Another aspect generally found with angular member towers is that more bracing members are required compared with tubular member towers owing to the buckling efficiency of CHS members. Thus, towers manufactured from angular sections require more erection preparation and cost. However, angular members pack better for the purpose of transportation; this, however does not necessarily imply lower cost (Nielsen & Stottrup-Andersen 2006).

Other special considerations with tubular sections are (Nielsen & Stottrup-Andersen 2006):

- interior surface protection must be provided to prevent corrosion from the inside of the member.
- drain holes must be provided to prevent water buildup on the inside of a closed tube.
- drain hole diameter should be at least  $\varnothing 15mm$ .

### 3.5 Conclusion

This chapter evaluates the performance of circular hollow section members compared with angular members. The two main criteria for comparing the performance of a member are mass and strength. In both cases, mass and strength, does the circular hollow sections outperform the conventional angular sections.

A table that compares various cross-sections in compression is shown. The comparison is for three different load cases with equivalent effective lengths. The single angular cross-section and I-beam is 2.3 times heavier compared with CHS. The back-to-back and cruciform angle section is 1.5 times heavier compared with the CHS.

In order to compare the strength between a CHS member and a angular member, the ratio between their respective moments of inertia were calculated. Two scenarios were considered; the first scenario does not include any limitations on the width to thickness ratio of the cross-section. The second

scenario includes the limits of Class 3 structural members in compression. The former calculation indicates that CHS members are 1.22 times stronger in compression and the latter calculation indicates that CHS members are 11.7 times stronger in compression compared with angular members.

The performance of the circular hollow cross-section versus the angular cross-section, in mass and strength, indicates that there is merit to continue to investigate the use of CHS for transmission towers.

Additionally, it was also shown that CHS members have 50% less wind resistance compared with angular members which also affects member selection. The build-up of ice is also less for CHS members than for angular members.

The main disadvantage of using CHS in power line towers are the higher cost associated with fabrication and the difficulty of climbing the long slender members. Special features would have to be included in the design and fabrication of the tower to allow for maintenance personnel to climb up the structure. Lastly, allowance has to be made to safely galvanize the tower members e.g. drain holes to allow internal protection as well as preventing air build-up.