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Advantages of use of Tubular/Hollow Sections over Conventional Open Sections in Hydro-Carbon Industry Structures

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***Abstract* - Tubular/ Hollow sections are gaining popularity in recent times, due to its higher strength-to-weight ratio than conventional open sections as well as for the reason that, hollow sections create lightweight and visually attractive structures. Due to their cross sectional configuration, such sections have inherent advantage in torsional buckling resistance capacity and axial load carrying capacity. Thus, its usage is continuously being increased in the hydrocarbon sector as well. Tubular/ hollow sections have been successfully used in many components of the structures, in which traditionally MC boxed sections were used due to its reduced requirement of welding, as compared to MC boxed sections. Therefore, it is imperative to analyze hollow sections and open rolled sections considering design strength and steel quantity requirements, to enable the designers to select the appropriate section, fitting the functional requirements and economics of the project. This study presents the comparative benefits of using hollow sections instead of open sections by presenting a theoretical comparison as well as a case study of three categories of industrial structures in hydrocarbon industry. Further it presents a detailed account of limitations in use of hollow sections on large scale in industrial structures of hydro carbon sector.**

Keywords -Hollow sections; Lateral torsional strength; Yield strength; IS 4923; Industrial structures; Weight-to-strength ratio.

Introduction

The excellent properties of the tubular shape have been recognized for a long time; there are examples of bridges etc. made of tubular sections as long back as last century. However, in the absence of readymade hollow sections, large tubular sections have been prepared by welding open sections such as channels or angles.

Hollow sections are gaining popularity in recent times, due to its higher strength-to-weight ratio than conventional sections as well as for the reason that, hollow sections create lightweight and visually attractive structures. Many examples in nature show the excellent properties of the tubular shape with regard to loading in compression, torsion and bending in all directions. For examples, tall slender plants such as bamboo tree or small weeds etc. Thus, use of hollow sections is in a way a nature inspired choice. Due to geometric configuration, such sections have inherent advantage in torsional buckling resistance capacity and axial load carrying capacity.

Even though predominant use of hollow section has been observed in infrastructure projects only, yet its usage is continuously increasing in the hydrocarbon sector as well. In the recent projects, tubular/ hollow sections have been successfully used in various structures, such as pipe supports, operating platforms and trusses in the shed or other structures, small pipe racks, or structural components such as vertical and plan bracings, longitudinal/ tie members of pipe racks and other structures etc. Many components of the structures, in which traditionally MC boxed sections were used, have been grossly taken over by hollow sections, due to its reduced requirement of welding, as compared to boxed sections fabricated from channels/angles.

Benefits of using Hollow Section over Conventional Open Sections-

Following has been the main reasons for increasing use of hollows sections-

I. Aesthetic Reasons-

Due to aesthetic reasons, hollow sections have been the first choice for buildings where structural members are exposed such as in airports, malls, exhibition centers and other amenity buildings. In structural members, as the length of member increases, their axial capacity

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decreases. The decrease in capacity is very less for hollow sections as compared to open sections. This makes hollow sections preferable choice for members of large span trusses. Thus, hollow sections are valuable in providing long span structures having a feel of openness and aesthetics which have always been an architect's delight.

II. Design benefits-

Hollow sections are made of similar steel as used for open steel sections, thus in principle there is no difference as long as mechanical and chemical properties are concerned. However, distribution of mass on cross sectional plane plays an important role in determining the strength-to-weight ratios of structural section. The more mass is placed away from the centroid of cross-sectional area, the more strength section has against Euler buckling and lateral-torsional buckling, which is required for a section to be loaded to its full compressive or bending strength. In this aspect, hollow sections (by having total mass placed away from centroid) have a major advantage over conventional I-sections, channels and angles, which have most of the mass placed near centroid or along axes passing though centroid (Fig. 1).

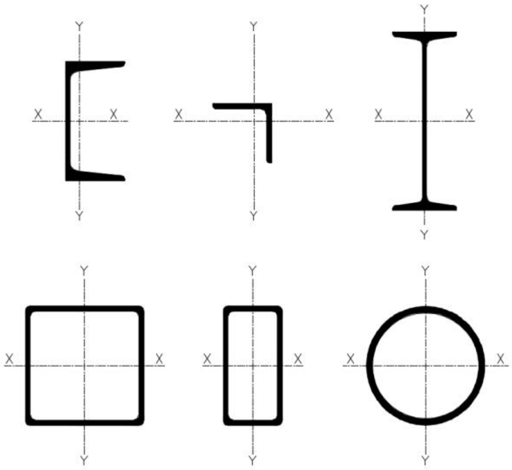

Fig. 1 Centroid (intersection of x- and y-axis) and mass distribution around centroid for different types of structural steel sections

Further, Table-I & II below show a comparison of unit weights of members required for a given Bending moment and Axial compression capacity. The percentage reduction in material is calculated and highlighted wherever there is a saving. Effective lengths of the members have been considered as 0m (fully restraint), 4m & 8m for bending as well as for axial compression to incorporate the effect of slenderness on member capacity.

TABLE-I: COMPARISON OF BENDING CAPACITIES

TABLE- I(A): OPEN AND HOLLOW SECTION REQUIRED FOR GIVEN BENDING CAPACITIES (L_{EFF}=0M)

	L_EFF=0M				
BENDING CAPACITY	I-SECTION	UNIT WEIGHT	HOLLOW SECTION	UNIT WEIGHT	DIFFERENCE IN WEIGHT
(IN KN-M)		(IN KG/M)		(IN KG/M)	
50	MB200	24.2	RHS200x100x6	26.4	9.09%
100	MB300	44.2	RHS280x100x6	33.94	-23.21%
150	MB300	44.2	SHS250x250x6	45.24	2.35%
200	MB300	44.2	RHS300x150x8	53.22	20.41%
250	MB400	61.5	RHS350x250x6	54.66	-11.12%
300	MB400	61.5	RHS400x300x6	64.08	4.20%
350	MB400	61.5	RHS400x300x6	64.08	4.20%
400	NPB 450X190X67.15	67.15	RHS500x200x6	64.08	-4.57%
450	NPB 450X190X67.15	67.15	RHS400x300x8	84.62	26.02%
500	NPB 500X200X79.36	79.36	SHS400x400x8	97.18	22.45%
550	NPB 500X200X79.36	79.36	SHS400x400x8	97.18	22.45%

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600	NPB 500X200X79.36	79.36	RHS500x300x8	97.18	22.45%
650	MB500	86.9	RHS500x300x8	97.18	11.83%
700	NPB 500X200X107.31	107.31	RHS500x300x10	120.43	12.23%
750	NPB 500X200X107.31	107.31	RHS500x300x10	120.43	12.23%
800	NPB 500X200X107.31	107.31	RHS500x300x10	120.43	12.23%
850	NPB 600X220X107.56	107.56	RHS500x200x14	143.74	33.64%
900	NPB 600X220X107.56	107.56	RHS500x300x14	165.72	54.07%
950	NPB 600X220X107.56	107.56	Hollow sections for these capacities are not available		-
1000	NPB 600X220X122.45	122.45			-

Table-i(b): Open and Hollow section required for given Bending Capacities (L_{EFF}=4m)

	L_eff=4m				
Bending Capacity	I-section	Unit weight	Hollow section	Unit Weight	Difference in weight
(in KN-m)		(in Kg/m)		(in Kg/m)	
50	MB300	44.2	RHS250x100x6	31.11	-29.62%
100	WPB 200X200X50.92	50.92	SHS220x220x6	39.59	-22.25%
150	MB400	61.5	SHS250x250x6	45.24	-26.44%
200	NPB 450X190X67.15	67.15	RHS350x250x6	54.66	-18.60%
250	NPB 450X190X67.15	67.15	RHS400x200x6	54.66	-18.60%
300	NPB 500X200X79.36	79.36	RHS400x300x6	64.08	-19.25%
350	NPB 500X200X79.36	79.36	RHS500x200x6	64.08	-19.25%
400	NPB 500X200X90.68	90.68	SHS350x350x8	84.62	-6.68%
450	NPB 500X200X107.31	107.31	RHS400x300x8	84.62	-21.14%
500	NPB 500X200X107.31	107.31	SHS400x400x8	97.18	-9.44%
550	NPB 600X220X107.56	107.56	SHS400x400x8	97.18	-9.65%
600	NPB 600X220X107.56	107.56	RHS500x300x8	97.18	-9.65%
650	NPB 600X220X107.56	107.56	RHS500x300x10	120.43	11.97%
700	NPB 600X220X122.45	122.45	RHS500x300x10	120.43	-1.65%
750	WPB 600X300X128.79	128.79	RHS500x300x10	120.43	-6.49%
800	WPB 600X300X128.79	128.79	SHS400x400x12	143.29	11.26%
850	WPB 700X300X149.89	149.89	RHS500x300x14	165.72	10.56%
900	WPB 700X300X149.89	149.89	Hollow sections for these capacities are not available		-
950	WPB 700X300X149.89	149.89			-
1000	WPB 700X300X149.89	149.89			-

Table-i(c): Open and Hollow section required for given Bending Capacities (L_{EFF}=8m)

	L_eff=8m				
Bending Capacity	I-section	Unit weight	Hollow section	Unit Weight	Difference in weight
(in KN-m)		(in Kg/m)		(in Kg/m)	
50	WPB 200X200X50.92	50.92	SHS220x220x6	39.59	-22.25%
100	NPB 450X190X67.15	67.15	SHS250x250x6	45.24	-32.63%
150	WPB 250X250X73	73.14	RHS350x250x6	54.66	-25.27%
200	WPB 300X300X100.84	100.84	RHS400x300x6	64.08	-36.45%
250	WPB 300X300X100.84	100.84	RHS400x300x6	64.08	-36.45%
300	WPB 300X300X117.03	117.03	SHS350x350x8	84.62	-27.69%
350	WPB 300X300X117.03	117.03	SHS350x350x8	84.62	-27.69%
400	WPB 300X300X117.03	117.03	SHS400x400x8	97.18	-16.96%
450	WPB 360X370X136.65	136.65	SHS400x400x8	97.18	-28.88%
500	WPB 360X370X136.65	136.65	SHS400x400x8	97.18	-28.88%
550	WPB 700X300X149.89	149.89	RHS500x300x10	120.43	-19.65%
600	WPB 700X300X149.89	149.89	RHS500x300x10	120.43	-19.65%
650	WPB 600X300X177.77	177.77	RHS500x300x10	120.43	-32.26%

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700	WPB 600X300X177.77	177.77	SHS400x400x12	143.29	-19.40%
750	WPB 600X300X177.77	177.77	Hollow sections for these capacities are not available		-
800	WPB 600X300X177.77	177.77			-
850	WPB 600X300X177.77	177.77			-
900	WPB 600X300X177.77	177.77			-
950	WPB 700X300X204.48	204.48			-
1000	WPB 700X300X204.48	204.48			-

From these tables, following observations are clear regarding the bending capacities of open sections vis-à-vis hollow sections-

i. At smaller effective lengths, especially in case of fully laterally supported beams, benefits of use of hollow sections are there only for a very small number of sections. Maximum bending strength that can be achieved by using hollow sections is only 900KN-m, which is quite lesser than that of parallel flange I-sections.

ii. As the effective length increases, bending capacity of I-sections decrease whereas capacity of hollow sections doesn't reduce much. Due to this, for larger effective lengths such as 6m and 8m, for any required bending capacity there is a more economical hollow section available than I-sections.

TABLE-II: COMPARISON OF AXIAL COMPRESSION CAPACITIES

Table-II(a): Open and Hollow section required for given Axial Compression Capacities (L_{eff}=0m)

	L_eff=0m				
Axial Capacity	I-section	Unit weight	Hollow section	Unit Weight	Difference in weight
(in kN)		(in Kg/m)		(in Kg/m)	
200	MB200	24.2	RHS60x40x6	7.56	-68.76%
400	MB200	24.2	RHS70x50x8	11.77	-51.36%
600	MB200	24.2	RHS120x60x6	15.1	-37.60%
800	MB200	24.2	SHS125x125x6	21.69	-10.37%
1000	MB300	44.2	SHS150x150x6	26.4	-40.27%
1200	MB300	44.2	RHS250x100x6	31.11	-29.62%
1400	MB300	44.2	RHS250x150x6	35.82	-18.96%
1600	MB300	44.2	SHS220x220x6	39.59	-10.43%
1800	WPB 200X200X50.92	50.92	SHS250x250x6	45.24	-11.15%
2000	WPB 200X200X50.92	50.92	SHS220x220x8	51.96	2.04%
2200	MB400	61.5	RHS350x250x6	54.66	-11.12%
2400	MB400	61.5	RHS300x200x8	59.5	-3.25%
2600	NPB 450X190X67.15	67.15	RHS300x150x10	65.48	-2.49%
2800	MB450	72.4	RHS400x200x8	72.06	-0.47%
3000	NPB 400X180X75.66	75.66	SHS220x220x12	75.46	-0.26%
3200	NPB 500X200X79.36	79.36	RHS500x200x8	84.62	6.63%
3400	MB500	86.9	RHS500x200x8	84.62	-2.62%
3600	NPB 500X200X90.68	90.68	RHS350x250x10	89.03	-1.82%
3800	WPB 300X300X100.84	100.84	SHS400x400x8	97.18	-3.63%
4000	WPB 300X300X100.84	100.84	RHS300x200x14	99.78	-1.05%
4200	NPB 500X200X107.31	107.31	RHS500x200x10	104.73	-2.40%
4400	WPB 300X300X117.03	117.03	RHS500x300x10	120.43	2.91%
4600	WPB 300X300X117.03	117.03	RHS500x300x10	120.43	2.91%
4800	NPB 600X220X122.45	122.45	RHS500x300x10	120.43	-1.65%
5000	WPB 600X300X128.79	128.79	RHS400x300x12	124.45	-3.37%
5200	WPB 600X300X128.79	128.79	RHS500x300x12	143.29	11.26%
5400	WPB 360X370X136.65	136.65	RHS500x300x12	143.29	4.86%
5600	WPB 700X300X149.89	149.89	RHS500x300x12	143.29	-4.40%
5800	WPB 700X300X149.89	149.89	RHS500x300x12	143.29	-4.40%
6000	WPB 700X300X149.89	149.89	RHS500x300x14	165.72	10.56%
6200	WPB 600X300X177.77	177.77	RHS500x300x14	165.72	-6.78%
6400	WPB 600X300X177.77	177.77	RHS500x300x14	165.72	-6.78%
6600	WPB 600X300X177.77	177.77	RHS500x300x14	165.72	-6.78%
6800	WPB 360X370X182.01	182.01	Hollow sections for these capacities are not available		-
7000	WPB 360X370X197.65	197.65			-
7200	WPB 360X370X197.65	197.65			-
7400	WPB 360X370X197.65	197.65			-

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7600	WPB 700X300X204.48	204.48			-
7800	WPB 700X300X204.48	204.48			-
8000	WPB 600X300X211.92	211.92			-

TABLE-II(B): OPEN AND HOLLOW SECTION REQUIRED FOR GIVEN AXIAL COMPRESSION CAPACITIES (L_{EFF}=4M)

	L_EFF=4M				
AXIAL CAPACITY	I-SECTION	UNIT WEIGHT	HOLLOW SECTION	UNIT WEIGHT	DIFFERENCE IN WEIGHT
(IN KN)		(IN KG/M)		(IN KG/M)	
200	MB300	44.2	SHS100x100x6	16.98	-61.58%
400	MB300	44.2	SHS125x125x6	21.69	-50.93%
600	WPB 200X200X50.92	50.92	SHS150x150x6	26.4	-48.15%
800	WPB 200X200X50.92	50.92	RHS240x120x6	32.05	-37.06%
1000	WPB 200X200X50.92	50.92	RHS250x150x6	35.82	-29.65%
1200	NPB 450X190X67.15	67.15	SHS220x220x6	39.59	-41.04%
1400	WPB 250X250X73	73.14	SHS250x250x6	45.24	-38.15%
1600	WPB 250X250X73	73.14	RHS300x200x6	45.24	-38.15%
1800	WPB 250X250X73	73.14	RHS350x250x6	54.66	-25.27%
2000	WPB 250X250X73	73.14	RHS350x250x6	54.66	-25.27%
2200	WPB 300X300X100.84	100.84	RHS400x300x6	64.08	-36.45%
2400	WPB 300X300X100.84	100.84	RHS400x300x6	64.08	-36.45%
2600	WPB 300X300X100.84	100.84	SHS300x300x8	72.06	-28.54%
2800	WPB 300X300X100.84	100.84	RHS500x200x8	84.62	-16.08%
3000	WPB 300X300X100.84	100.84	RHS500x200x8	84.62	-16.08%
3200	WPB 300X300X117.03	117.03	RHS400x300x8	84.62	-27.69%
3400	WPB 300X300X117.03	117.03	SHS400x400x8	97.18	-16.96%
3600	WPB 300X300X117.03	117.03	SHS400x400x8	97.18	-16.96%
3800	WPB 600X300X128.79	128.79	SHS350x350x10	104.73	-18.68%
4000	WPB 600X300X128.79	128.79	RHS400x300x10	104.73	-18.68%
4200	WPB 360X370X136.65	136.65	RHS500x300x10	120.43	-11.87%
4400	WPB 360X370X136.65	136.65	RHS500x300x10	120.43	-11.87%
4600	WPB 360X370X136.65	136.65	RHS500x300x10	120.43	-11.87%
4800	WPB 360X370X150.87	150.87	RHS500x300x12	143.29	-5.02%
5000	WPB 600X300X177.77	177.77	RHS500x300x12	143.29	-19.40%
5200	WPB 600X300X177.77	177.77	RHS500x300x12	143.29	-19.40%
5400	WPB 600X300X177.77	177.77	RHS500x300x12	143.29	-19.40%
5600	WPB 600X300X177.77	177.77	RHS500x300x14	165.72	-6.78%
5800	WPB 360X370X182.01	182.01	RHS500x300x14	165.72	-8.95%
6000	WPB 360X370X197.65	197.65	RHS500x300x14	165.72	-16.15%
6200	WPB 360X370X197.65	197.65	RHS500x300x14	165.72	-16.15%
6400	WPB 360X370X197.65	197.65	HOLLOW SECTIONS FOR THESE CAPACITIES ARE NOT AVAILABLE		
6600	WPB 600X300X211.92	211.92			
6800	WPB 800X300X224.37	224.37			
7000	WPB 700X300X240.51	240.51			
7200	WPB 700X300X240.51	240.51			
7400	WPB 700X300X240.51	240.51			
7600	WPB 900X300X251.61	251.61			
7800	WPB 800X300X262.33	262.33			
8000	WPB 800X300X262.33	262.33			

TABLE-II(C): OPEN AND HOLLOW SECTION REQUIRED FOR GIVEN AXIAL COMPRESSION CAPACITIES (LEFF=8M)

	L_EFF=8M				
AXIAL CAPACITY	I-SECTION	UNIT WEIGHT	HOLLOW SECTION	UNIT WEIGHT	DIFFERENCE IN WEIGHT
(IN KN)		(IN KG/M)		(IN KG/M)	
200	WPB 200X200X50.92	50.92	SHS150x150x6	26.4	-48.15%
400	WPB 250X250X73	73.14	SHS180x180x6	32.05	-56.18%
600	WPB 250X250X73	73.14	SHS220x220x6	39.59	-45.87%
800	WPB 250X250X73	73.14	SHS250x250x6	45.24	-38.15%
1000	WPB 300X300X100.84	100.84	SHS250x250x6	45.24	-55.14%
1200	WPB 300X300X100.84	100.84	RHS350x250x6	54.66	-45.80%
1400	WPB 300X300X100.84	100.84	RHS350x250x6	54.66	-45.80%
1600	WPB 300X300X117.03	117.03	RHS400x300x6	64.08	-45.24%
1800	WPB 300X300X117.03	117.03	RHS400x300x6	64.08	-45.24%
2000	WPB 360X370X136.65	136.65	SHS350x350x8	84.62	-38.08%
2200	WPB 360X370X136.65	136.65	SHS350x350x8	84.62	-38.08%
2400	WPB 360X370X136.65	136.65	SHS350x350x8	84.62	-38.08%
2600	WPB 360X370X136.65	136.65	SHS400x400x8	97.18	-28.88%

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2800	WPB 360X370X150.87	150.87	SHS400x400x8	97.18	-35.59%
3000	WPB 360X370X150.87	150.87	SHS400x400x8	97.18	-35.59%
3200	WPB 360X370X182.01	182.01	RHS500x300x10	120.43	-33.83%
3400	WPB 360X370X182.01	182.01	RHS500x300x10	120.43	-33.83%
3600	WPB 360X370X182.01	182.01	RHS500x300x10	120.43	-33.83%
3800	WPB 360X370X197.65	197.65	SHS400x400x10	120.44	-39.06%
4000	WPB 360X370X197.65	197.65	RHS500x300x12	143.29	-27.50%
4200	WPB 600X300X285.47	285.47	RHS500x300x12	143.29	-49.81%
4400	I-SECTIONS FOR THESE CAPACITIES ARE NOT AVAILABLE		RHS500x300x12	143.29	-
4600			SHS400x400x12	143.29	-
4800			RHS500x300x14	165.72	-
5000			RHS500x300x14	165.72	-

From the tables above, following observations can be made regarding axial compression capacities of hollow section in comparison to that of I-sections-

i. At smaller effective lengths, benefits of use of hollow sections are there only for a very small number of sections. Maximum Axial compressive strength that can be achieved by using hollow sections is only 6600KN, which is quite lesser than that of parallel flange I-sections.
ii. As the effective length increases, compressive strength of I-sections decreases whereas capacity of hollow sections doesn't reduce much. Due to this, for larger effective lengths such as 6m and 8m, for any required bending capacity there is a more economical hollow section available than I-sections.

As per a study [2], comparison between the required mass of open and hollow sections for a given load and for a buckling length of 3 m, is presented in Fig. 2. It shows that in those cases where loads are small, leading to lighter (and hence relatively slender) sections from stress point of view, hollow sections provide a great advantage (considerably lower use of material). However, if loads are heavier, resulting in requirement of heavy sections from stress considerations, the advantage (in %) will be lower. This is due to the fact that heavier open sections, similar to hollow sections, have inherently better design properties about minor axis than lighter sections. It means that for a given length, heavier open sections have lesser slenderness and thus higher allowable strength ratio than lighter open sections. Thus, if hollow sections are used in place of lighter open sections (e.g., MB200, MB250, MB300 etc.), reduction in strength due to slenderness can be avoided but same may not be the case for heavy open sections such as WPB600x300x128 or higher.

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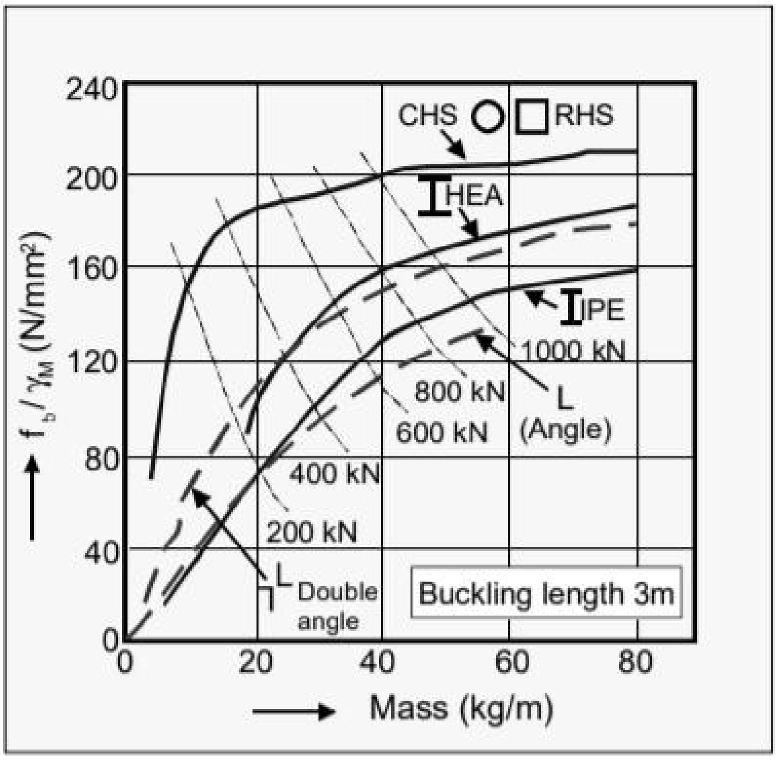

Fig. 2: Mass required for Open and Hollow Sections for a given Load

III. Lesser Requirement of Corrosion Protection

The closed shape without sharp corners reduces the area to be protected and extends the corrosion protection life. Fig. 3 below shows surfaces requiring painting or other corrosion protect in hollow and open sections.

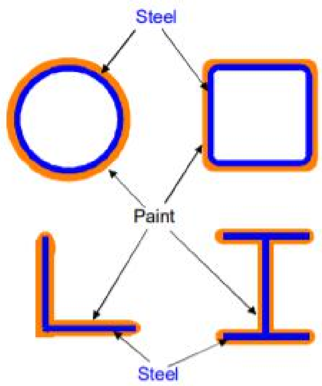

Fig. 3: Surfaces Requiring Painting in Hollow and Open Sections

IV. Material and Cost savings

As explained above, due to better utilization of mass hollow sections exhibit higher strength as compared to open section of same weight and same effective length and hence result in significant savings in material and cost.

Although the manufacturing costs of hollow sections are higher than for other sections, leading to higher unit material cost, but reduction in overall quantity of steel required have resulted in lower overall cost for structure.

In order to establish the actual savings in different types of structure sample design have been performed for T-supports, Pipe rack and Technological structures; first using conventional open sections or built-up box sections and then using standard hollow sections. The results of this comparative study are presented below-

A. T-supports

Comparison presented in Table-III shows that there is approximately 2.78-11.23% savings in material if hollow sections are used in place of built-up channel box sections for design of T-supports of various width and height (Fig. 3a)-

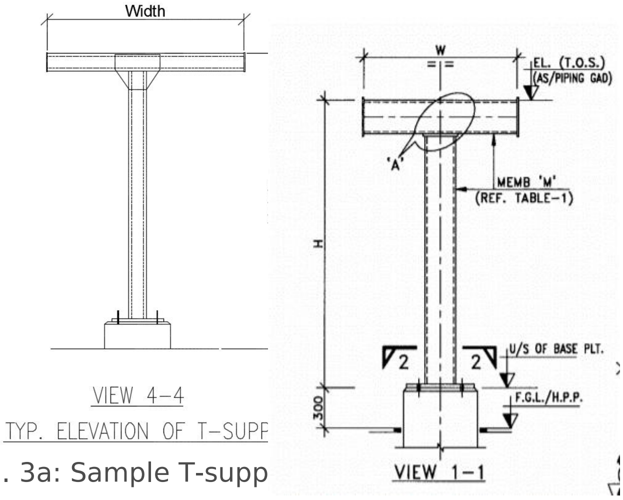

Fig. 3a: Sample T-supp

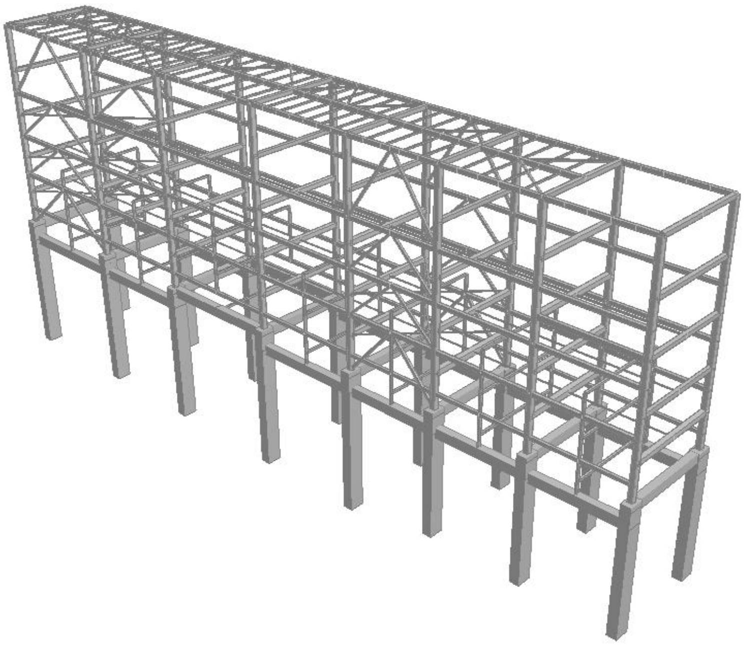

Fig. 3b: Sample Pipe Rack

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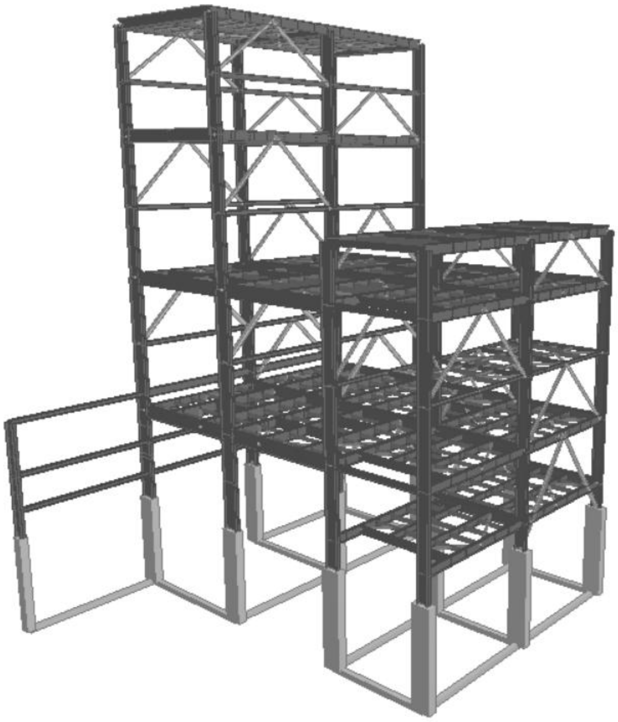

Fig. 3c: Sample Technological Structure

Fig. 3: Sample Industrial Structures Selected for Study

TABLE III
(TITLE: REDUCTION IN MTO FOR T-SUPPORTS)

T-SUPPORT DETAILS			STANDARD T-SUPPORT USING MC [ ] SECTION		STANDARD T-SUPPORT USING SHS/RHS SECTION			%AGE REDUCTION IN WEIGHT
TYPE	WIDTH (MM)	HEIGHT (MM)	MEMBER	TOTAL WEIGHT (KG)	MEMBER TYPE	MEMBER	TOTAL WEIGHT (KG)	
A	750	2000	ISMC150[]	92.40	RHS	RHS220X140X6	88.28	4.46%
					SHS	SHS180X180X6	88.22	4.52%
B	750	3000	ISMC200[]	167.25	RHS	RHS260X180X6	148.50	11.21%
					SHS	SHS220X220X6	148.46	11.23%
C	750	4000	ISMC250[]	290.70	RHS	RHS300x200x8	280.73	3.43%
					SHS	SHS250X250X8	282.63	2.78%
D	1500	1500	ISMC150[]	100.80	RHS	RHS220X140X6	96.30	4.46%
					SHS	SHS180X180X6	96.24	4.52%
E	1500	2300	ISMC200[]	169.48	RHS	RHS260X180X6	150.48	11.21%
					SHS	SHS220X220X6	150.44	11.23%
F	1500	3000	ISMC250[]	275.40	RHS	RHS300x200x8	265.95	3.43%
					SHS	SHS250X250X8	267.75	2.78%

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B. Pipe rack

A comparison of Structural steel MTO for a sample Pipe rack (Fig. 3b) designed with two above mentioned section categories is presented in Table-IV. It shows that there is approximately 6.27% savings in material if hollow sections are used in place of conventional open sections.

C. Technological Structure

A comparison of Structural steel MTO for a sample Technological Structure (Fig. 3c) designed with two above mentioned section categories is presented in Table-V. It shows that there is approximately 14.67% savings in material if hollow sections are used in place of conventional open sections.

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TABLE-IV
(TITLE: REDUCTION IN MTO FOR SAMPLE PIPE RACK)

SECTION TYPE USED IN SAMPLE PIPE RACK	STEEL MTO (IN MT)	REDUCTION DUE TO USE OF HOLLOW SECTIONS
CONVENTIONAL OPEN SECTIONS	104.25	6.27%
HOLLOW SECTIONS	98.16	

TABLE-V
(TITLE: REDUCTION IN MTO FOR SAMPLE TECHNOLOGICAL STRUCTURE)

SECTION TYPE USED IN SAMPLE TECHNOLOGICAL STRUCTURE	STEEL MTO (IN MT)	REDUCTION DUE TO USE OF HOLLOW SECTIONS
CONVENTIONAL OPEN SECTIONS	210.81	14.67%
HOLLOW SECTIONS	179.90	

PROBLEMS IN USE OF HOLLOW SECTIONS-

In spite of the benefits listed above, use of hollow sections in industrial structures has been limited by various factors which are being overtaken by manufacturers and designers both with advancement of technology and domain knowledge.

I. Limitations on availability

Hollow sections are manufactured (and used) in accordance with IS: 4923 (Hollow Steel Sections for Structural Use), by either Seamless or Hot finished welded or Electric resistance or induction welded process. So far hollow sections in India have been available for very small sections sizes. Reason being that use of hollow section for structural purposes is governed by IS 4923 which included structural properties of members up to 108 mm x 180 mm and 172 mm x 92 mm only. With new IS 4923-2017, hollow section up to 400mm x 400mm and 500 mm x 300 mm size have been incorporated and large hollow section sizes are now being manufactured. Still, there is need for even larger sections as heavy industrial structures in hydrocarbon sector require the rolled sections even up to WPB 900 x 300 x 291, in order to support large equipments and to satisfy stringent design criteria applicable to them.

Other aspect of availability limitation is that even though hollow sections are being manufactured in a larger spectrum of sizes but the same are not available in market very easily especially if the quantity required for a particular section size is small. However, this is being taken care of by manufactures by establishing manufacturing units all across the country, strengthening distribution network and upgrading rolling process to ensure easy changes in process for producing any section size as per order. Further designers are also ensuring to limit the number of sections used in design to the minimum to avoid generating demand for large number of sections with small quantities.

II. Limitation on Bending Capacity

Though axial capacities of SHS or RHS are substantial, flexural capacities of these sections are not so impressive, resulting in hindrance of its global usage in all structures, which is required for heavily loaded elements for strength & serviceability requirements.

III. Limitation on Use for Certain Type of Members Only

Hollow sections (especially SHS sections) have similar properties about both the axis. This property is useful for members carrying axial and bending stresses. However in case of purely bending members, such as beams of operating floors etc, minor axis strength is not that much of importance due to presence plane bracing. In such cases, SHS sections usually are in fact a wrong choice of section type. RHS section can be a better choice for such members depending on the unsupported length of compression flange.

IV. Limitation due to Connection Detailing

These sections being closed from all sides, application of stiffener plates, at the point of stress concentration, such as beam-column junctions (Fig. 4(a)), equipment supporting members etc. are not possible. There are studies being done to use external stiffeners at stress concentration points (Fig. 4(b)) however this makes connection very cumbersome and unaesthetic. This discourages the usage of these sections for such applications.

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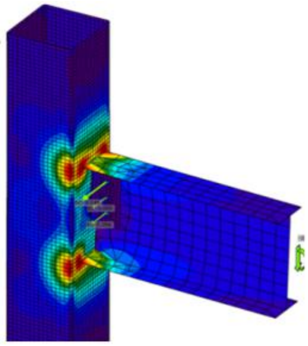

Fig. 4(a): Stress concentration at joints in hollow sections

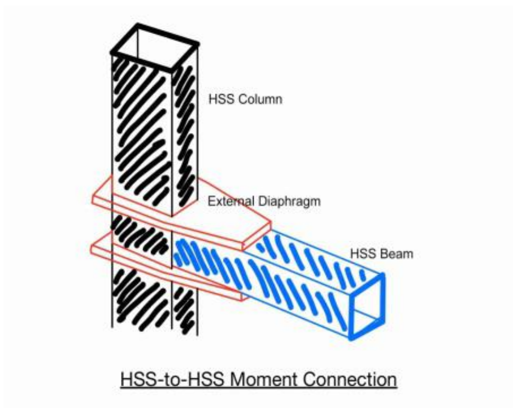

Fig. 4(b): External diaphragm at stress concentration points

Fig. 4: Connection in Hollow sections

CONCLUSION-

So far, use of hollow sections in large industrial structures has been limited to bracing and tie members only and thus percentage of hollow sections in total weight of steel used in structures is approximately 7-10% only. Major limitation in using hollow sections as main members is the scarcity of connection detailing for hollow sections when used as beams and columns especially in a moment frames. Based on feedback from industry, prominent hollow section manufacturers have started joint efforts with educational and research institutes for development of standard details for various type of connections used in hydrocarbon industry. Once such details are finalized and successfully adopted, use of hollow sections is expected to rise rapidly.

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