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Suitability of Stiffened Sheet Metal as Against a Plate Metal in Fabrication Works: A scientific approach towards metal craft work

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Abstract—This paper is an attempt to deduce on the economical selection of a plate versus sheet metal for use in fabrication works. The method adopted is theory and practical applications of the principles of Strength of Materials (SOM) to a plate, a sheet metal and a stiffened sheet metal. The results confirmed that in spite of less rigidity due to less thickness; sheet metal strength could be enhanced considerably as against the strength of a thick plate by appropriately applying the principles of stiffening. This ability of increasing the strength/weight ratio by stiffening sheet metals helps in cost control on the shop floor.

Keywords—Deduce, Plate, Sheet metal, SOM, Stiffening

I. INTRODUCTION

The basic principle of stiffening can be illustrated by supporting a tumbler of water on a piece of note paper bridging two other tumblers as shown in the "Fig. 1" and "Fig. 2" below. From the figures it is clear that a sheet metal panel will not support a very great load due to the thinness of the material. A metal plate of the same surface area will support a fairly substantial load because of its extra thickness. But, although the metal plate is much more rigid than the sheet metal panel, this rigidity is obtained at the expense of considerable additional weight. Therefore, more the weight, more the rigidity and as per the prevailing market cost rate per kg, more would be the cost.

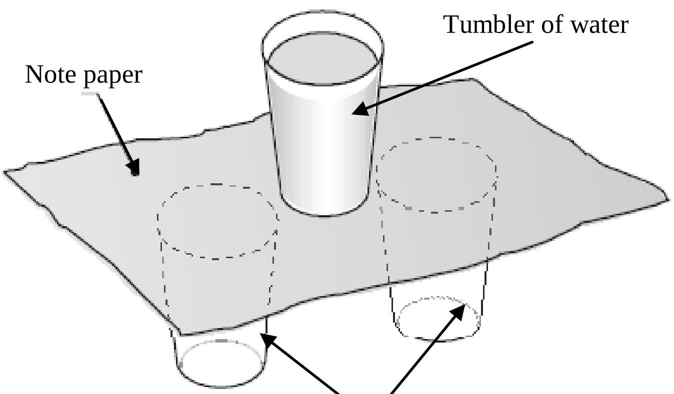

Figure 1. Note paper

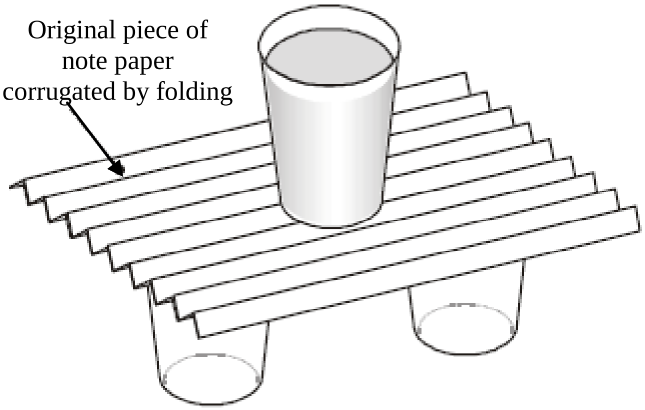

Figure 2. Note paper stiffened by corrugation

Strength/weight ratio is an important factor in the fabrication industry and by stiffening the sheet metal in an appropriate manner, it is possible to produce a multiplicity of light fabrications which are very rigid and strong. The comparative parameters as from [1], to justify the above illustration for stiffening using a corrugated note paper in lieu of a sheet metal are as shown in "Table 1." below.

TABLE 1. COMPARISON OF STEEL AND NOTE PAPER

Material	Elastic Moduls, E MN/m^2	Density, r Kg/m^3	Tensile Stiffness Index, $E^w = E/r$ MNm/kg	Bending Stiffness Index, $S^w = E^w/12.r^2$ Nm^7/kg^3
Steel	210000	7800	25	0,03
CF composites	200000	2000	100	2,00
Paper	15600	700	22	3,70

A. Literature Review

The following conclusions reviewed from [2] – [14] on the sheet metals types, alternative materials, fabrication processes, methods for stiffening sheet metal components, etc. are compiled in the "Table 2" to be utilized for defining the objectives of this paper.

TABLE 2. METHODS OF STIFFENING

	Pros	Cons	Remarks
A. Plate component	More rigidity More stiffness	More weight More cost	Not economical
B. Sheet component used as it is (without stiffening)	Less weight Less cost	Less rigidity Less stiffness	Not economical unless used in proper orientation with respect to applied load
C. Sheet component fabricated (less thickness)	Less weight Less cost More rigidity More stiffness	Additional cost of fabrication or changeover to composite materials	Economical but subject to conditions in fabrication process used (Refer Figure 5.)
D. Sheet component fabricated (medium thickness but less than for a plate)	More weight More cost More rigidity More stiffness	Additional cost of fabrication or changeover to composite materials	Economical but subject to conditions in fabrication process used. (Refer Figure 6.)
E. Web stiffeners (structural sections)	Less weight Less cost More rigidity More stiffness	Additional cost of fabrication or changeover to composite materials	Economical but subject to conditions in fabrication process used. (Refer Figure 7.)

B. Objective

Study of the stiffening methods by applying the principles of Strength of Materials and hence conclude their suitability for fabrication in metal craft works with relevant illustrations that depict;

- Improved strength and rigidity for the intended function
- Safe edge for handling
- Aesthetic look for marketing

II. RESULTS AND DISCUSSION

First method: Utilize the existing geometry available to improve strength but by employing a different orientation and same loading as shown in "Fig. 3" and the comparison of the deflection parameter for both the cases is as shown in "Table 3."

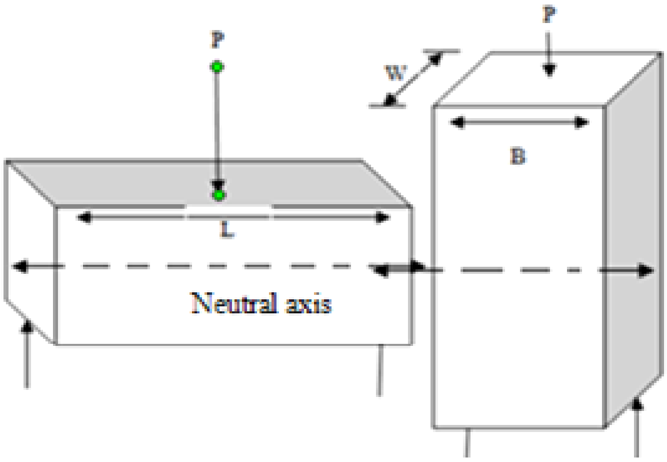

Figure 3. Stiffening using change in orientation

TABLE 3. COMPARISON OF TWO ORIENTATIONS FOR LOADING

Sr. Nos.	Variables	Assumed values	Deflection 'y'*10^{-6}mm	Moment of Inertia 'I'
1	Loading perpendicular to L*W	L= 50mm, B= 15mm, W= 20mm, E=2*10^5 N/mm^2, P= 10N	**9.26**	14062.5mm^4
2	Loading perpendicular to B*W		**0.02**	156250mm^4

Thus, the second position with a higher Moment of Inertia results in a lesser amount of downward deflection. The results so obtained may be deduced that the deflection of a component under a load reduces when the extreme fibers of the component lies far away from the neutral axis. The more farther the distance more is the ability to sustain any bending load. This obviously implies that any plate material having considerable thickness with respect to other dimensions is able to withstand bending loads very easily unlike a sheet metal. But, the fabricability of a sheet metal to be folded, joined by bolts, rivets, adhesives, etc. enables the above condition to be achieved as shown in "Fig. 4".

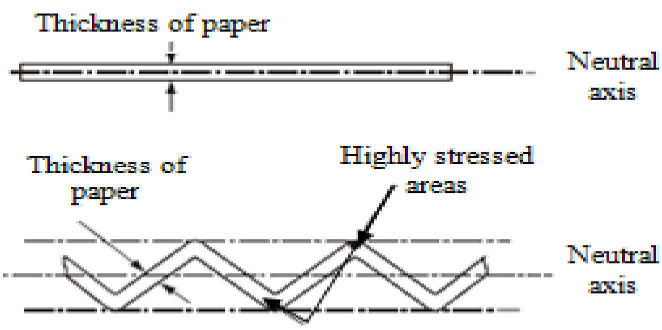

Figure 4. Principle of stiffening

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The above method of corrugation of the note paper (analogous to a sheet metal) helps to separate the extreme fibers to lie much more beyond the neutral axis as compared to before the corrugation. This is similar to a plate metal which also has its extreme fibers far away from the neutral axis. So, stiffening obtained improves strength with less weight as compared to a similar plate with similar strength but more weight as seen from "Table 4." below.

TABLE 4. COMPARATIVE STIFFNESS FOR CORRUGATED SHEET METAL

Sandwich panel	Load applied (kN)	Total deformation (mm)	Stiffness (kN/mm)	Total weight (N)
3 curve	13.5	0.215	**62.79**	161.7
4 curve	13.5	0.042	**321.43**	168.7

(Source: IJERT, Vol. 1 Issue 8, October – 2012)

Hence, for a given length and height of the structure, increasing the number of curved waves (3 waves to 4 waves) the strength increases effectively. For increase of 4% weight, the strength is increased to 66% and increase in stiffness to 80.47%. Hence, from the above discussion when the number of curved waves increases to infinity (i.e. manifests as a solid plate) the tremendous increase in strength, stiffness and weight are evident.

Second method: In this method, the same reasoning as in the First method is achieved by adopting fabrication methods on the sheet metal by folding/hem (single and/or double), punching a lightening hole, etc. Consider a single fold given to the sheet metal on all the four sides to attain strength and rigidity in both planes of bending as in "Fig. 5". Now applying the principles of strength of materials we have the comparative figures in favor of the fold as in "Table 5."

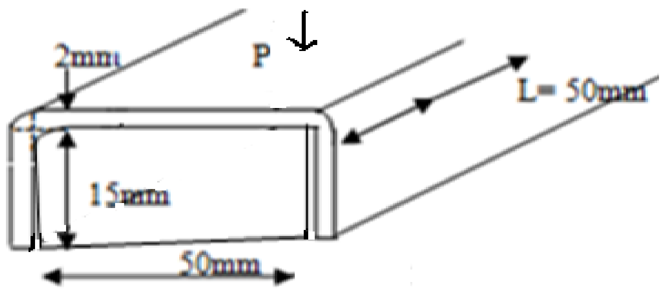


Figure 5. Stiffening by fold

TABLE 5. COMPARISON OF TWO ORIENTATIONS FOR LOADING

Sr. Nos.	Variables	Assumed values	Deflection 'y' mm	Moment of Inertia 'I'
1	Loading perpendicular to W*t (W= 80mm)	t= 2mm, W= 80mm (50mm after folding), E=2*10^5 N/mm^2, P= 10N	**0.0099**	53.33 mm^4
2	Loading perpendicular to W*t (W= 50mm)		**0.0025*10^{-2}**	5102.39 mm^4
2	Loading perpendicular to L*t (Assume, L= W= 50mm)		**0.0025*10^{-2}**	5102.39 mm^4

Third method: In this method, applicable for thicknesses that disable the sheet metals to undergo folding and/or bending operations, the above reasoning is again achieved by applying stiffeners/reinforcements at the required locations to attain strength and rigidity in both planes of bending as in "Fig. 6" and comparative figures in favor for the same as in "Table 6." The necessary stiffeners may be fabricated separately and then assembled by means of rivets or bolted joints.

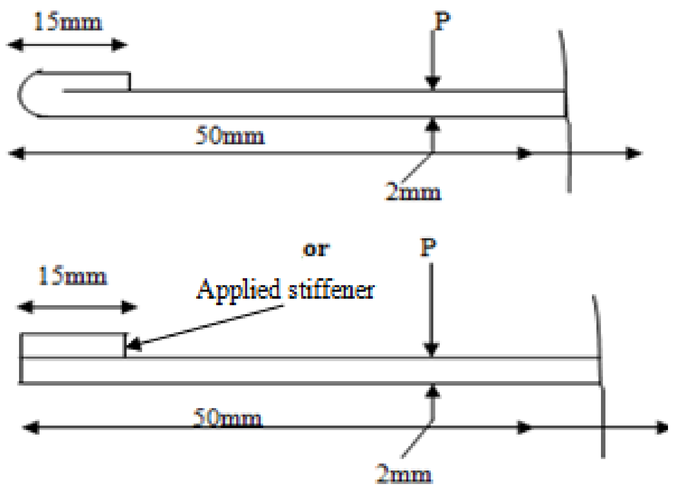


Figure 6. Stiffening by hem or applied stiffener

TABLE 6. COMPARISON OF TWO ORIENTATIONS FOR LOADING

Sr. Nos.	Variables	Assumed values	Deflection 'y' mm	Moment of Inertia 'I'
1	Loading perpendicular to W*t (W= 80mm)	t= 2mm, W= 80mm (50mm after folding), E=2*10^5 N/mm^2, P= 10N	**0.0099**	53.33 mm^4
2	Loading perpendicular to W*t (W= 50mm)		**0.064*10^{-2}**	203.33 mm^4
2	Loading perpendicular to L*t (Assume, L= W= 50mm)		**0.064*10^{-2}**	203.33 mm^4

Another category in this method involves stiffening of structural sections, especially I – sections/columns/beams with added stiffeners which may be conceptualized as a combination of I - section and a rectangular solid beam as in "Fig. 7" and then compared as shown in "Table 7".

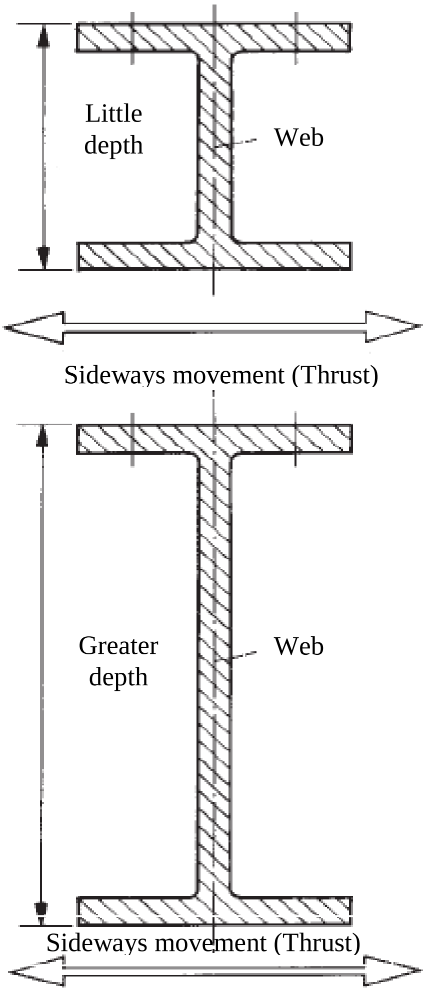


Figure 7. Web stiffening

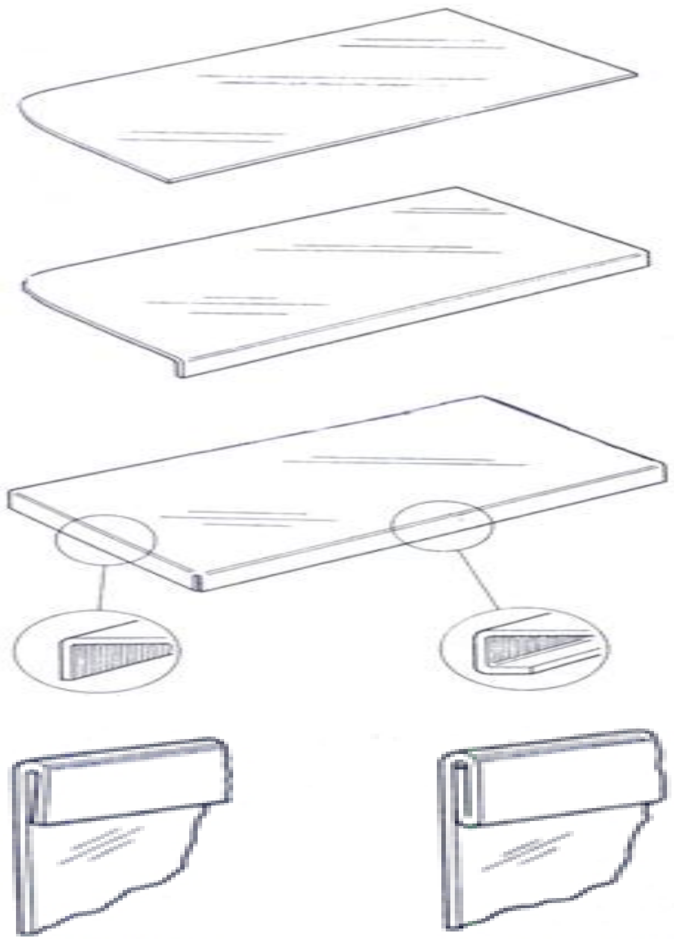
TABLE 7. COMPARISON OF STRUCTURAL SECTION ALTERNATIVES

	Pros	Cons	Remarks
Rectangular beam	Good strength Good rigidity	High weight High cost	Not economical
I - beam	Good strength Good rigidity	Low weight Low cost Unsuitable for sideways thrust	Uneconomical for eccentric loadings
Web stiffened I - beam	Good strength Good rigidity Suitable for sideways thrust	Medium weight and cost subjected to conditions in fabrication process	Section combination of rectangular beam and I – beam giving a greater value of moment of inertia at the sections of stiffener for the entire span of the I - beam

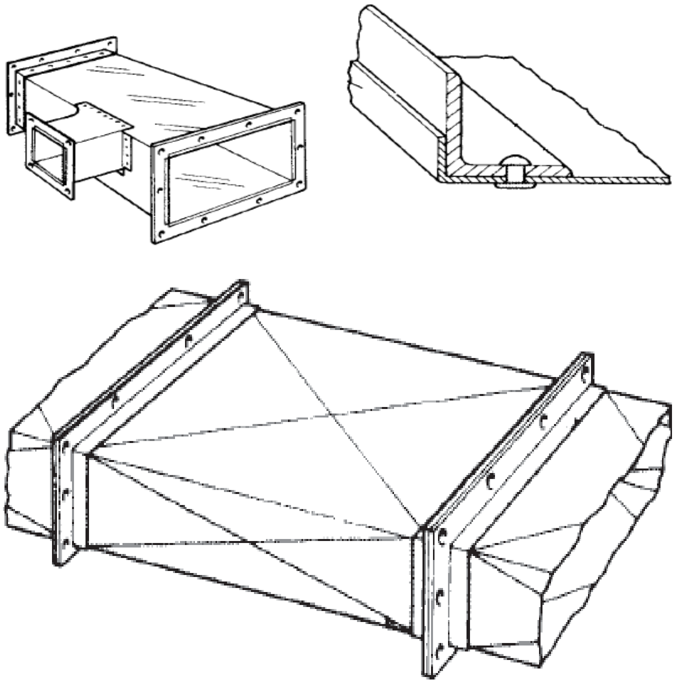
III. CONCLUSION

Fabrication works make use of plate and sheet metals. The various fabrication processes involved are marking/measuring, cutting, folding/bending, rolling, presswork, joining, cleaning/painting. Depending upon the end use/application of the fabricated component an evaluation of the strength of stiffened sheet metal in terms of reduced deflection subjected to a point load as against a plate material helps offset the associated disadvantages of sheet metal. This implies that the cost of employing the appropriate stiffening operation (material & labor cost) ought to be less than cost of the plate material. This again implies that the stiffening operation ought to be as simple as possible. Some illustrations from [5] for the same are as given below to complete the objectives of the paper.

Stiffening methods for small thickness are labor intensive and involves manual interventions as shown in “Fig. 8” below.



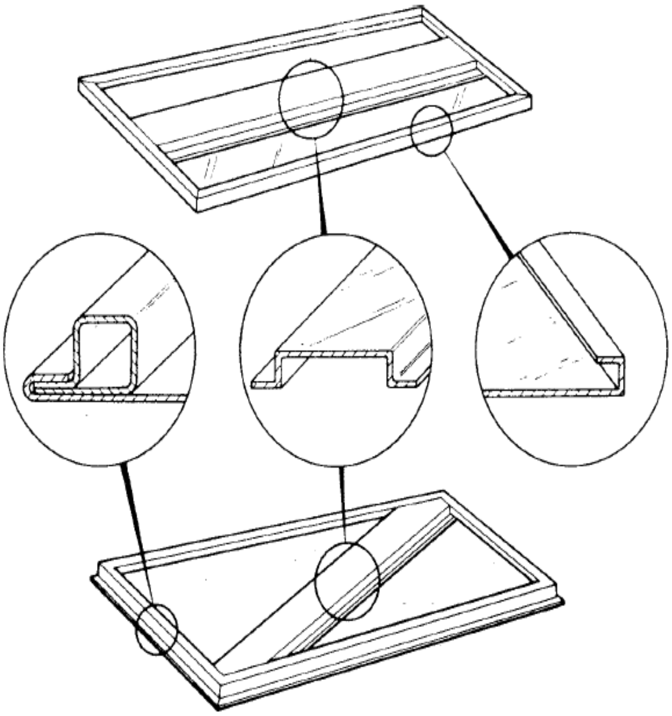
a) Folds/Hems



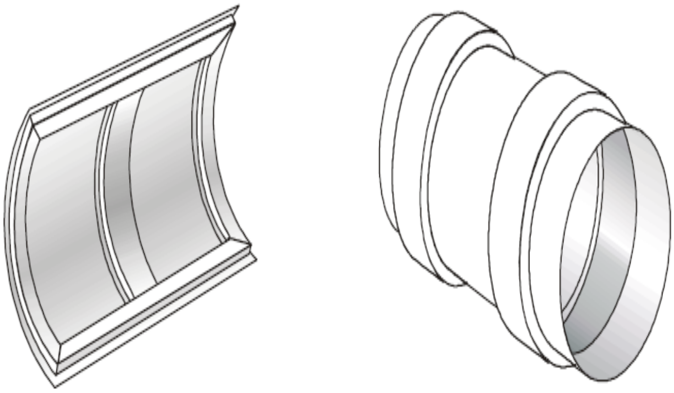
b) Diamond break

Figure 8. Sheet component fabricated (less thickness)

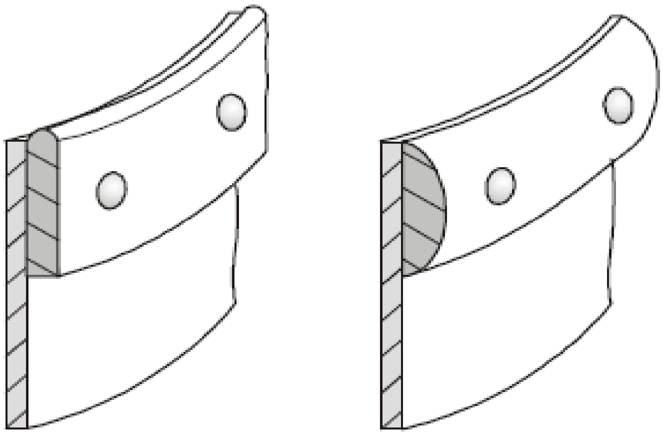
Stiffening methods for more thickness are also labor intensive and involves manual/ machine interventions as seen in the “Fig. 9” and “Fig. 10” (for structural sections) below.



a) Large panel stiffening

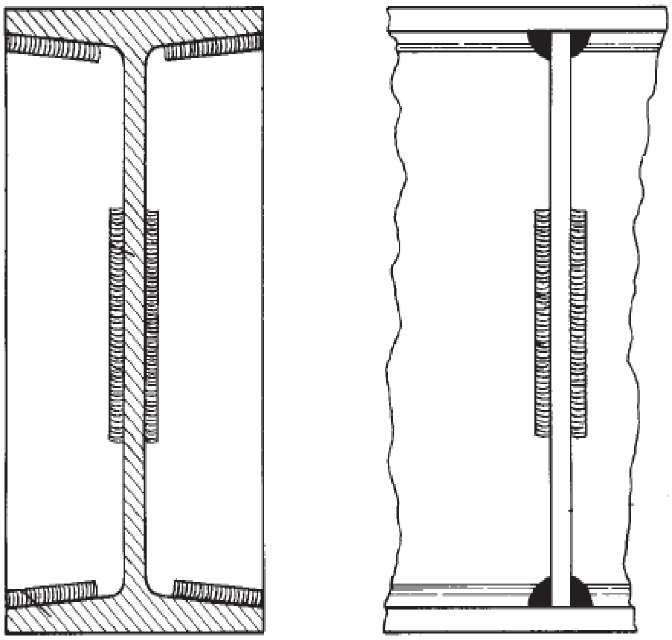


b) Circular component stiffening (before or after rolling)

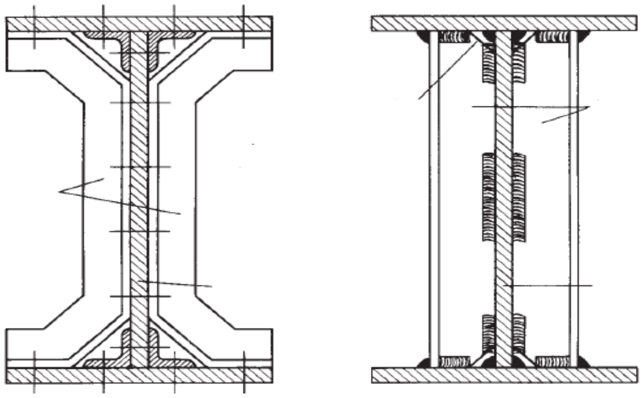


c) Stiffening thick sheet metals

Figure 9. Sheet component fabricated (medium to less than plate thickness)



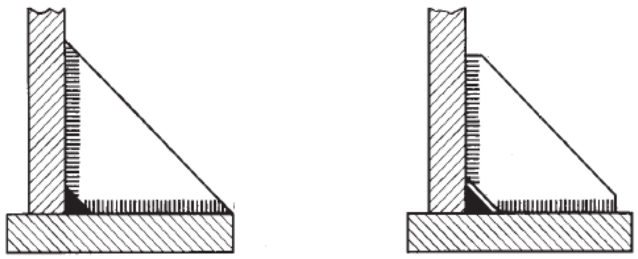
a) Welded joints



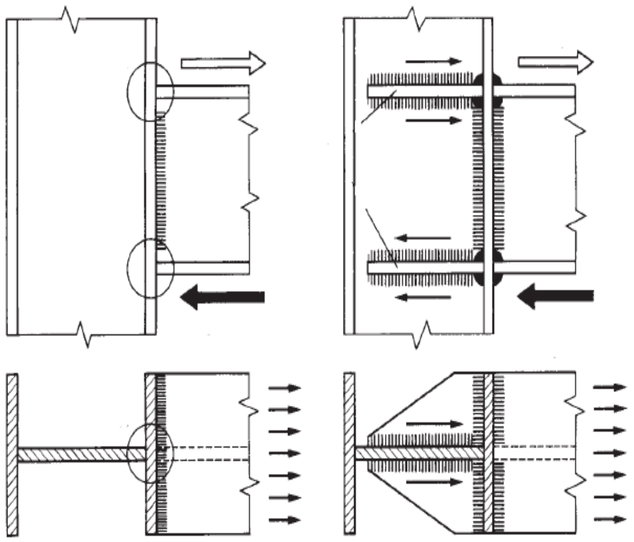
b) I- beam of plates bolted/riveted

Figure 10. Methods of web stiffening

Stiffening a flange is done when a single fillet weld has to be used, the other side being inaccessible for welding and if otherwise this single weld would be subjected to bending as shown in the “Fig. 11” below.



a) Stiffening for welded flanged connection



b) Stiffening of welded connection between two I-section members

Figure 11. Stiffening with gusset plates

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