

"Improved C-Section Structural Member"

FIELD OF THE INVENTION

This invention relates to a structural member which is intended to be used as a load bearing element in a skeletal structure. The invention has been developed as a purlin for use in a roof-supporting building structure and the invention is hereinafter described in the context of a purlin. However, it will be understood that the invention does have broader application, to a structural member which is suitable for use in any load bearing structure.

BACKGROUND OF THE INVENTION

A purlin typically is formed as a rolled steel member having a C-section. As viewed in section a basic form of purlin has two spaced-apart parallel flanges which are joined at one end by a flat web and which are formed at the other end with relatively small inwardly directed lips. The lips associated with the respective flanges lie in the same plane and lie parallel to the web. This basic configuration has been modified by various manufacturers to include return lips (to be hereinafter described) and/or to include longitudinally extending deformations within the web. The modifications have been made deliberately in an attempt to increase the bending strength and/or for the purpose of producing application specific section geometries.

The present invention has been developed with the object of providing a section configuration that provides for increased strength relative to that obtained from the basic purlin configuration and, importantly, which has regard for factors that influence bending strength under different load and/or support conditions.

Various factors are relevant to the design of purlins that are required to withstand loads that cause bending about the major principal axis. If purlins are braced against lateral and torsional deformation the main factors that determine the design load are the span and the section bending capacity, the latter being the

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product of the effective section modulus about the major principal axis and the yield stress of the material forming the section. When comparing purlins of the same material for use over the same span, the effective
5 section modulus about the major principal axis controls the design. The effective section modulus depends upon the disposition of material in the section and the slenderness of the component parts of the section. Section slenderness predisposes the purlin to buckling
10 and it can be shown that, at short half-wavelengths, two modes of buckling can occur. These modes are referred to herein as "local" and "distortional" buckling and they will be described in more detail in a following drawing-related description.

15 If a purlin is unbraced over a relatively long length and is subject to bending about the major principal axis, two factors function principally to control the section design. These are referred to herein as "flexural-torsional" buckling and "twisting"
20 deformation and they are described also in more detail in the following drawing-related description. If a sufficiently long unbraced length of purlin is considered, the flexural-torsional buckling will control the section design and not the section bending capacity
25 as determined by the abovementioned local and distortional buckling.

In the context of purlin twisting, which results typically from eccentric loading, the eccentricity from the centre of the purlin flange to the shear centre of
30 the section governs the magnitude of torque applied to and, hence, twisting experienced by a purlin section. For this reason the eccentricity of the shear centre should be minimised in the design of a purlin section, at least in relation to purlins that are subjected to
35 significant twisting forces.

Previously mentioned modifications to the basic purlin section (i.e., inclusion of return lips and deformation of the web) have resulted in improved

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resistance to local and distortional buckling but improvements in resistance to flexural-torsional buckling have not been so significant. Given that it is flexural-torsional buckling that controls the section design in at least some applications of purlins, the present invention is directed to the creation of a purlin structure which provides for optimisation of resistance to the three forms of buckling.

An obvious way of improving resistance to flexural-torsional buckling would be to increase the width of each of the section flanges, but this would merely exacerbate the potential for local buckling. Also, the resistance to flexural-torsional buckling might be increased by increasing the length of the lip returns, but this would produce an increase in the shear centre eccentricity and so enhance the potential for twisting of the purlin under load.

SUMMARY OF THE INVENTION

The present invention seeks to reconcile these conflicting difficulties by providing an elongate structural member which is cold formed from rolled steel and which is formed with a C-shaped cross-section (or "C-section") having two spaced-apart parallel flanges, a web joining one end of the respective flanges, a lip located at the other end of each of the flanges, a lip return projecting into the C-shaped cross-section from the marginal edge of each of the lips, and at least one longitudinally extending channel-shaped recess formed within the web and projecting into the C-shaped cross-section. The structural member is characterised in that each of the lips projects in a direction outwardly from the C-shaped cross-section to form an obtuse angle θ with the associated flange and in that the angle θ is greater than 90° but not greater than 135° .

It has been determined that, by forming both of the lips in a manner to establish the obtuse angle θ between the lips and the associated flanges, the flexural-torsional buckling stress of the structural member is

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enhanced without substantially increasing the potential for local and distortional buckling. This determination has been made by performing finite strip buckling analyses in the design of the member. For details of
5 finite strip buckling analysis reference may be made to the publication "Design of Cold-Formed Steel Structures" (second edition), Australian Institute of Steel Construction, 1994 (ISBN 0 909945 70 5) by G J Hancock.

PREFERRED FEATURES OF THE INVENTION

10 The structural member preferably is formed so that the angle θ between each of the flanges and the associated lips lies within the range 95° to 125° and most preferably within the range 105° to 120° .

The width of the lips and the lip returns will be
15 determined in part by other sectional dimensions of the structural member and by load bearing requirements of the member. Similar conditions and factors relating to the shear centre eccentricity of the member will determine the width and, more particularly, the depth of the
20 channel-shaped recess within the web.

However, each lip preferably has a width equal to 20% to 60% of the width of the associated flange and most preferably has a width equal to 30% to 60% of the width of the associated flange. Also, each lip return
25 preferably has a width equal to 30% to 100% of the associated lip width and most preferably has a width equal to 30% to 80% of the associated lip width.

When a single channel-shaped recess is formed within the web, the channel-shaped recess preferably has a width
30 within the range 25% to 80% of the total width of the web in which it is located, and the channel-shaped recess preferably has a depth within the range 3 to 20 times the thickness of the metal forming the web.

In circumstances where the purlin in situ is not
35 subjected to a significant twisting force, such as when the purlin is braced against twisting by being secured adequately to a supporting structure by way of a bracing member, the need to minimise the shear centre

eccentricity may become less critical than the need to minimise the extent to which the channel-shaped recess projects into the C-section. This situation may arise in circumstances when ancillary elements such as cleats and brackets are to be secured to the surface of the web.

Therefore, as an alternative to a relatively deep single channel-shaped recess within the web, a plurality of shallow channels may be formed in the web for the purpose of functioning in much the same manner as a single, deeper channel-shaped recess by increasing the local buckling stress level. When a plurality of channel-shaped recesses is formed in the web, each channel-shaped recess preferably has a width in the order of 5% to 20% of the total width of the web and preferably has a depth within the range 0.5 to 3.0 times the thickness of the metal forming the web.

When a plurality of channel-shaped recesses is formed within the web, four such channel-shaped recesses preferably are formed in spaced-apart parallel relationship. Also, each channel-shaped recess preferably has an arcuate cross-section.

The invention will be more fully understood from the following description of alternative (preferred) embodiments of a roof support purlin and from the following comparative analysis made between purlins of various configurations. The description is provided with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings -

Figures 1 and 2 show prior art C-section purlins, Figure 3 shows a first preferred form of C-section purlin in accordance with the present invention, Figures 4, 5 and 6 show diagrammatically three different types of buckling that may occur in a purlin under load conditions, Figure 7 shows diagrammatically twisting deformation as may occur in a purlin under load conditions, Figure 8 shows graphs of buckling stress versus buckled

half-wavelengths for three different purlin sections, Figure 9 shows the embodiment of the C-section purlin as illustrated in Figure 3 but with dimension legends that are referred to in Table 1 in the specification,

- 5 Figure 10 shows a second preferred form of a C-section purlin in accordance with the present invention, and Figure 11 shows the same purlin as illustrated in Figure 10 but with dimension legends included that are referred to in Table 2 in the specification.

10 DETAILED DESCRIPTION OF THE INVENTION

Reference is made to the prior art C-section purlins of Figures 1 and 2 before proceeding to describe the preferred form of purlin that has been developed to meet the underlying principles of the present invention.

- 15 The basic C-section purlin configuration, as shown in Figure 1, is cold formed from rolled steel and has two spaced-apart parallel flanges 10 which are joined at one end by a flat web 11. The other end of each flange 10 is formed with a relatively small lip 12. The two lips 12
20 lie in the same plane and lie parallel to the web 11.

- A successful modification of the basic purlin configuration is shown in Figure 2. It also comprises a C-section purlin but includes a return lip 13 at the marginal edge of each of the lips 12. The return lips 13
25 project into the C-section and lie parallel to the flanges 10. The modified purlin further includes a longitudinally extending channel-shaped recess 14 in the web. The channel-shaped recess 14 typically has a depth in the region of 1.5 to 4.0 times the thickness of the
30 metal from which the purlin is formed.

- When subjected to finite strip buckling analyses, the modified purlin of Figure 2 exhibits local buckling and distortional buckling at stress levels significantly greater than those applicable to the basic purlin
35 configuration of Figure 1. The effects of such local buckling and distortional buckling are illustrated in Figures 4 and 5 respectively, and the buckling stress levels applicable to the prior art purlins of Figures 1

and 2 are graphed in curves A and B respectively in Figure 8.

It can be determined, again using finite strip buckling analyses, that the inclusion of the channel-shaped recess 14 in the web of the purlin shown in Figure 2 causes a significant increase in the local buckling stress level and that the lip returns 13 contribute to a substantial increase in the distortional buckling stress level. However, as can be seen from Figure 8, the advantages of the modified (Figure 2) prior art purlin are not so pronounced at larger half-wavelengths where flexural-torsional buckling, as illustrated in Figure 6, becomes the controlling factor. That is, whilst curve B shows a higher flexural-torsional buckling stress level for the modified purlin of Figure 2 than curve A shows for the basic purlin of Figure 1, the difference becomes progressively less significant with increasing half-wavelengths. As a consequence of the section profile that characterises the modified purlin (due in part to the relatively shallow channel-shaped recess 14), the shear centre eccentricity of the modified purlin is increased relative to that of the basic purlin.

The shear centre eccentricity (e) is identified in Figure 7 of the drawings, which figure also illustrates the effect of twisting deformation. The potential for twisting deformation increases with shear centre eccentricity.

The purlin section that is shown in Figure 3 has been developed to improve upon the flexural-torsional buckling characteristics of the modified Figure 2 purlin, whilst maintaining relatively high local and distortional buckling stress levels and reducing the shear centre eccentricity (e) to a level approaching that of the basic prior art purlin of Figure 1.

As shown in Figure 3, the preferred form of purlin has a superficial similarity with the prior art purlins of Figures 1 and 2 and the same reference numerals are employed to identify like parts. However, the purlin as

illustrated in Figure 3 is characterised by the inclusion of lips 15 which are inclined outwardly from the C-section. Each lip forms an obtuse angle θ with its associated flange and, as will be clear from the following description, benefits may be derived by making the angle θ something greater than 90° but less than 180° . As indicated previously, the lips preferably are inclined at an angle θ between 95° and 125° and most preferably between 105° and 120° .

The preferred form of purlin as shown in Figure 3 also has a relatively deep longitudinally extending channel-shaped recess 16 which is formed within the web 11 and which projects into the C-section. The channel-shaped recess preferably has a depth which is in the order of 3 to 20 times the thickness of the web 11.

In developing the purlin section that is shown in Figure 3, the basic purlin of Figure 1 was first adapted by increasing the effective width of the flanges 10 by inclining the lips 15. This had the effect of increasing the flexural-torsional buckling stress level by a significant extent, increasing the local buckling stress level by a small amount and reducing the distortional buckling stress level by a significant amount. It also had the effect of increasing the shear centre eccentricity by a small but significant extent.

The distortional buckling stress level is improved by increasing the stiffness of the lip 15 for movement in the vertical direction and, thus, by increasing the length of the lips 15 and/or increasing the length of the return lips 13. A greater advantage is obtained by increasing the length of the lips 15 because an increase in the length of the return lips 13 will not produce as great an increase in the unbraced section capacity as increasing the length of the lip 15.

The relatively deep channel 16 is incorporated in the section shown in Figure 3 to produce an effective reduction in the shear centre eccentricity.

Dimensions that have been developed in creation of the specific purlin section as illustrated in Figure 3 are identified in Figure 9 and shown in the following Table 1. The dimensions applicable to the Figure 3 embodiment are compared with corresponding dimensions of prior art purlins of the type shown in Figures 1 and 2.

TABLE 1

Dimension	Purlin Section		
	Fig. 1	Fig. 2	Fig. 3
D(mm)	200	200	200
B	75	75	75
l	16	28	38
b	0	10	10
d	0	62	52
i	0	4	15
t	1.5	1.5	1.5
θ (degrees)	90	90	105

As can be seen from Figure 8 (curve C), the C-section purlin as shown in Figure 3 and having the dimensions provided in Table 1 exhibits local and distortional buckling stress levels at 443 MPa and 419 MPa respectively, both of these being close to the normal material yield stress of 450 MPa. When used as a purlin section bent about the major principal axis, the newly developed purlin has its greatest advantage over the prior art purlins in unbraced designs and designs with widely spaced braces where flexural-torsional buckling controls the design strength. The flexural-torsional buckling stresses for an unbraced length of 5,000 mm have been shown to be approximately 28% higher than the modified prior art purlin structure and 72% higher than the basic prior art purlin structure for corresponding steel increases of 8% and 20% respectively. The local and distortional buckling stresses are comparable with

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those of the modified prior art purlin section and substantially higher than those of the basic prior art purlin section. The loading eccentricity is comparable with the basic prior art purlin section and substantially less than that of the modified prior art purlin section. Hence, the advantageous features of both of the (basic and modified) prior art purlin sections have been maintained whilst improving the flexural-torsional buckling capacity.

10 The purlin which is shown in Figure 10 is similar to that which is shown in Figure 3 and the same reference numerals are used to identify like parts. However, the purlin embodiment as shown in Figure 10 has been developed to accommodate the mounting of ancillary
15 elements such as cleats and brackets (not shown) to the web 11 and it is formed with four parallel channel-shaped recesses 17. The channel-shaped recesses 17 are provided to contribute to improvement of the local buckling stress level of the purlin and, whilst they do not serve to
20 reduce the shear centre eccentricity to the same extent as the relatively deep channel-shaped recess 16 shown in Figure 3, the channel-shaped recesses 17 will be appropriate in purlins in which a marginally larger shear centre eccentricity may be tolerated.

25 Each of the channel-shaped recesses 17 is provided with a generally arcuate form which blends smoothly into the web 11. Each recess projects into the C-section of the purlin by an amount (i.e. to a depth) equal to approximately 0.5 to 3.0 times the thickness of the metal
30 forming the web, depending upon other dimensional and load supporting requirements of the purlin.

Typical dimensions applicable to the purlin embodiment of Figure 10 and identified by the legends shown in Figure 11 are provided in the following Table.

TABLE 2

Dimension	Figure 10 Purlin Section		
	Type 1	Type 2	Type 3
D (mm)	100	150	200
B	50	60	73
ℓ	17	22	25
b	10	10	11
t	1.2	1.5	1.5
i	1.0	1.5	1.5
G	14	25	25
S	21	41	41
θ (degrees)	105	105	105

The purlin which is shown in Figure 10 and having the dimensions provided in Table 2, Type 3, has been shown to exhibit local and distortional buckling stress levels at 457 MPa and 427 MPa respectively. The flexural-torsional buckling stresses for an unbraced length of 5000 mm have been shown to be approximately 7% higher than the modified prior art purlin structure (as shown in Figure 2) and 39% higher than the basic prior art purlin structure (as shown in Figure 1) for corresponding steel increases of 0% and 10% respectively.

It will be understood that normal engineering practice should be applied to the fabrication of the above described purlins and that intersecting elements of the purlins will be joined by fillets of appropriate radius. For example, the flanges 10 may be joined to the web 11 in each case by fillets of radius 10 mm, and the lips 15 may be joined to the adjacent flange 10 and lip returns 13 by fillets of radius 5 mm. In the case of the channel-shaped recesses 17 in the Figure 10 embodiment, each recess might be formed with a 3 mm radius and be blended into the web by a fillet of 3 mm radius.

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It will also be understood that the purlins may be fabricated by using any known forming procedure, for example by cold forming rolled steel that has been produced by either a cold rolling or a hot rolling process.

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THE CLAIMS

1. An elongate structural member which is cold formed from rolled steel and which is formed with a C-shaped cross-section having two spaced-apart parallel flanges, a web joining one end of the respective flanges, a lip located at the other end of each of the flanges, a lip return projecting into the C-shaped cross-section from the marginal edge of each of the lips, and at least one longitudinally extending channel-shaped recess formed within the web and projecting into the C-shaped cross-section; characterised in that each of the lips projects in a direction outwardly from the C-shaped cross-section to form an obtuse angle θ with the associated flange and in that the angle θ is greater than 90° but not greater than 135° .

2. The structural member as claimed in claim 1 wherein the angle θ between each of the flanges and the associated lips lies within the range 95° to 125° inclusive.

3. The structural member as claimed in claim 1 wherein the angle θ between each of the flanges and the associated lips lies within the range 105° to 120° inclusive.

4. The structural member as claimed in any one of claims 1 to 3 wherein each lip has a width equal to 20% to 60% of the width of the associated flange.

5. The structural member as claimed in claim 4 wherein each lip has a width not less than 30% of the width of the associated flange.

6. The structural member as claimed in any one of the preceding claims wherein each lip return has a width equal to 30% to 100% of the associated lip width.

7. The structural member as claimed in claim 6 wherein each lip return has a width not greater than 80% of the associated lip width.

8. The structural member as claimed in any one of the preceding claims wherein both lip returns are disposed substantially parallel to the flanges.



9. The structural member as claimed in any one of the preceding claims wherein a single said channel-shaped recess is formed within the web, the channel-shaped recess having a width within the range 25% to 80% of the total width of the web and having a depth within the range 3 to 20 times the thickness of the metal forming the web.

10. The structural member as claimed in any one of claims 1 to 8 wherein a single said channel-shaped recess is formed within the web, the channel-shaped recess having a width equal to approximately 50% of the total width of the web and having a depth equal to approximately ten times the thickness of the metal forming the web.

11. The structural member as claimed in any one of claims 1 to 8 wherein a plurality of the channel-shaped recesses is formed within the web, the channel-shaped recesses being disposed in parallel, spaced-apart relationship.

12. The structural member as claimed in any one of claims 1 to 8 wherein four of the channel-shaped recesses are formed within the web in parallel, spaced-apart relationship.

13. The structural member as claimed in claim 11 or claim 12 wherein each of the channel-shaped recesses has a depth within the range 0.5 to 3.0 times the thickness of the metal forming the web.

14. The structural member as claimed in any one of claims 11 to 13 wherein each of the channel-shaped recesses has an arcuate cross-sectional form.

15. An elongate structural member which is cold formed from rolled steel, substantially as shown in Figure 3 or Figure 10 of the accompanying drawings and substantially as hereinbefore described with reference thereto.

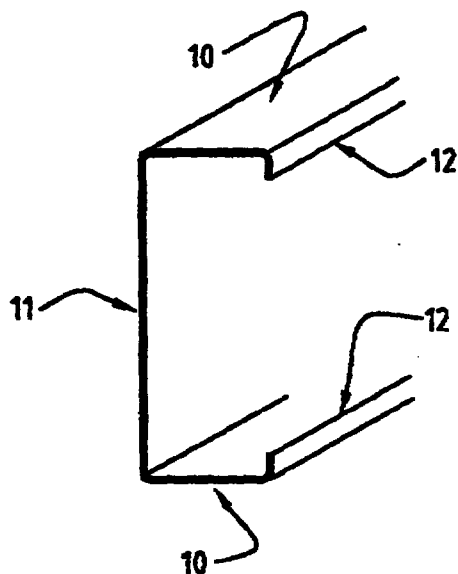


FIG. 1

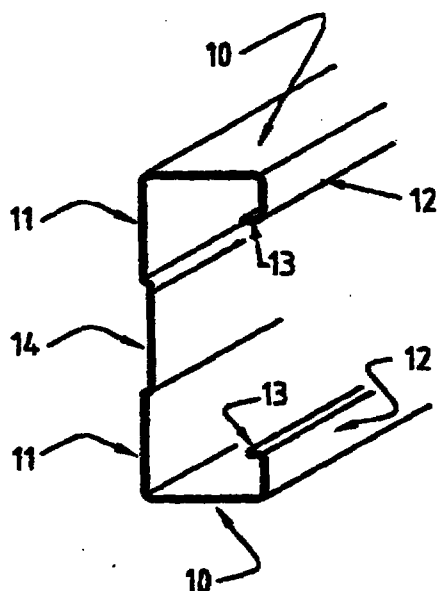


FIG. 2

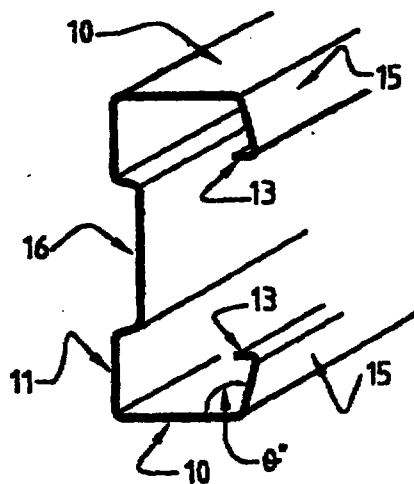


FIG. 3

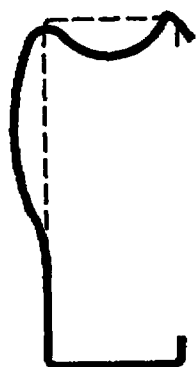


FIG. 4



FIG. 5

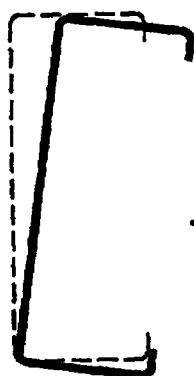


FIG. 6

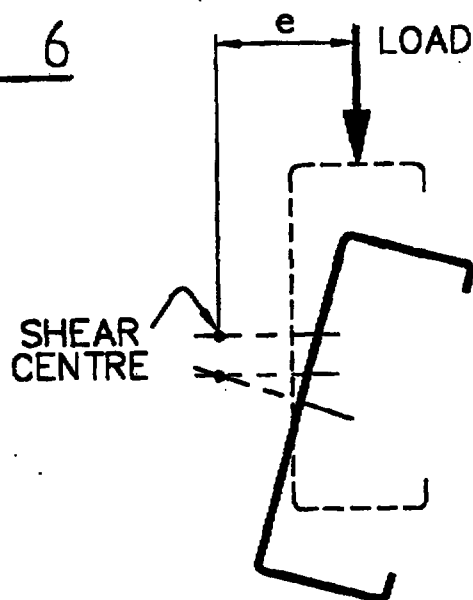


FIG. 7

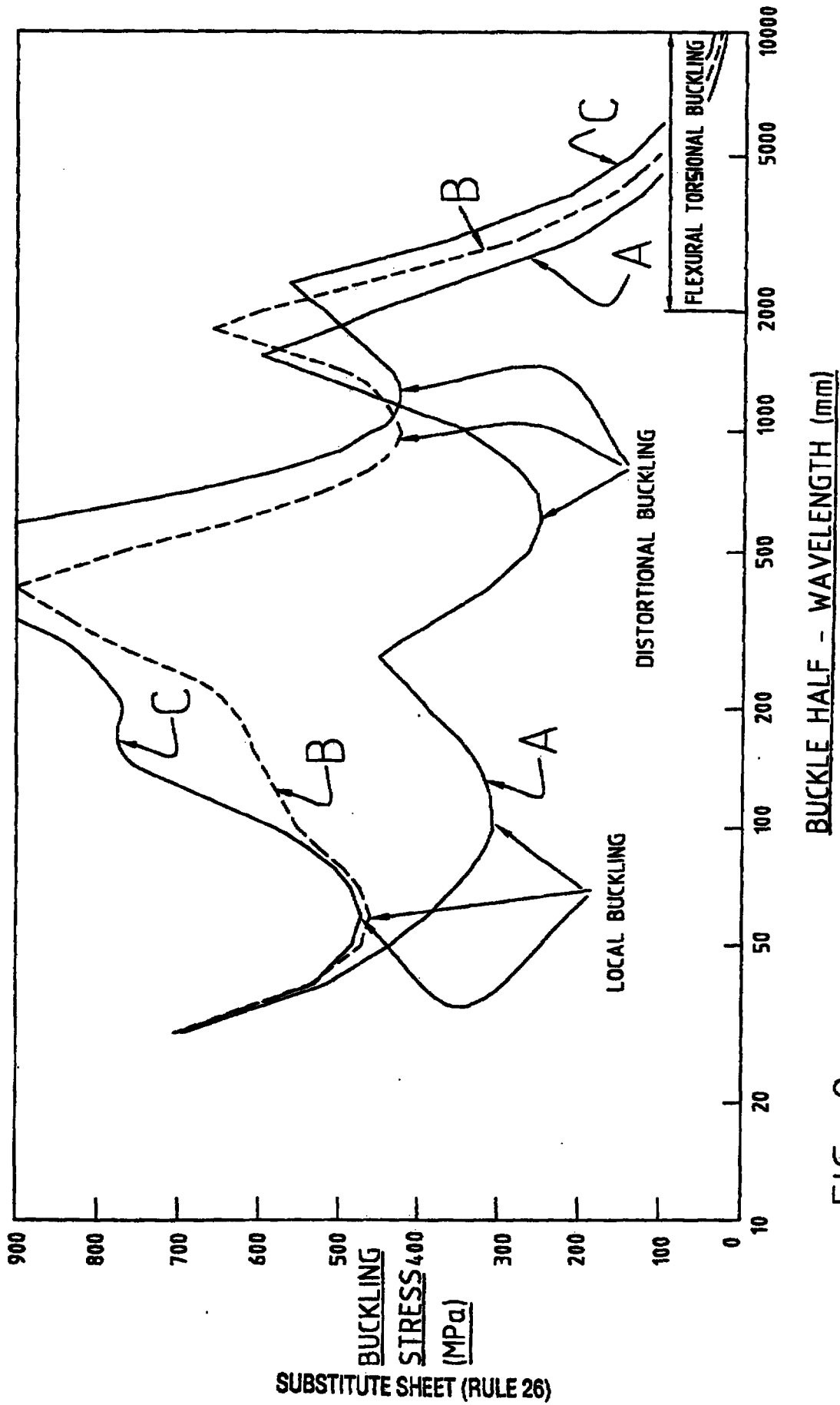


FIG. 8

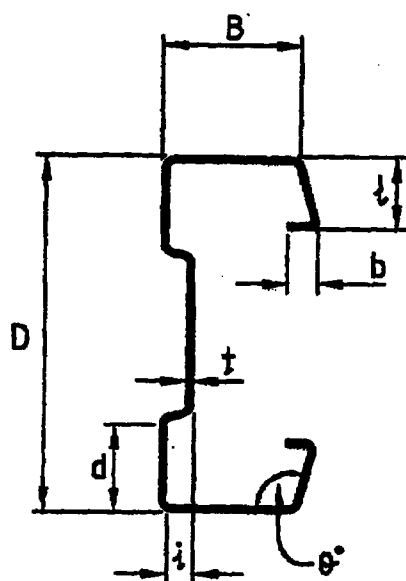


FIG. 9

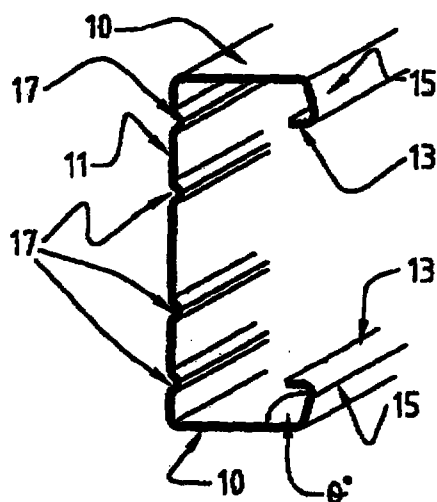


FIG. 10

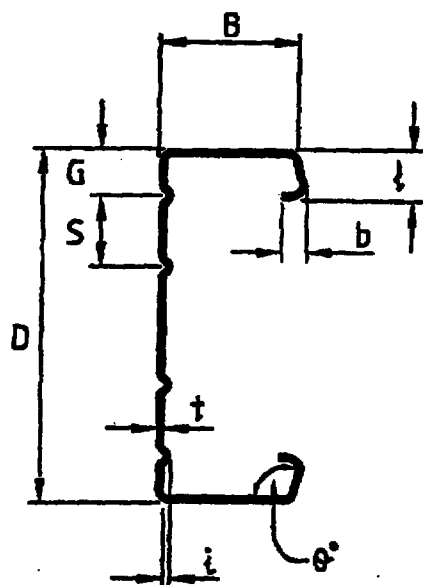


FIG. 11

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(54) Title: **IMPROVED C-SECTION STRUCTURAL MEMBER**

(57) Abstract

An elongate structural member which is cold formed from rolled steel and which is in the form of a purlin. The structural member has a C-shaped cross section composed of two spaced-apart parallel flanges (10), a web (11) joining one end of the respective flanges, a lip (15) located at the other end of each of the flanges, a lip return (13) projecting into the C-shaped cross section from the marginal edge of each of the lips (15), and at least one longitudinally extending channel-shaped recess (16 or 17) formed within the web (11) and projecting into the C-shaped cross section. The structural member is characterized in that both of the lips (15) project outwardly from the C-shaped section to form an obtuse angle θ with the respective flanges. In forming both of the lips so as to establish the obtuse angle θ between the lips and the associated flanges, the flexural-torsional buckling stress of the structural member is enhanced without substantially increasing the potential for local and distortional buckling.

