

An apparatus for supporting a reflector and a method of assembling the same

5 Field of the Invention

The present invention relates to a support structure for supporting a reflector of any usable shape, scale (which includes nanotechnology and applications in MMIC), and contour that may be needed to concentrate or disperse light, sound, or electromagnetic waves. It
10 relates more particularly, but not exclusively, to a reflector for concentrating solar radiation. The invention also relates to a method of assembling the support structure.

15 Background of the Invention

Large parabolic reflectors, particularly ones measuring ten feet in width and larger have been used in a variety of applications, including as solar radiation concentrators. The production cost of these applications, however, has always been high, which has limited their
20 use to a subset of special, well-funded applications.

Material science, design and manufacturing process are three factors dictating such high production costs. Usually, the support structure is designed for a particular reflector, and is not usable for reflectors of
25 different sizes. For example, support structures designed for reflectors deployed in protected environments will not be able to withstand weather, including wind, precipitation and temperature swings, without damage to either themselves or to the reflector.

To reduce production costs, an assortment of large reflector structures of various forms have been built using relatively small reflective elements –hexagonal, triangular, square or circular in shape. An example of so built parabolic reflector is described in U.S. Patent 5 6,064,352. A further parabolic reflector support structure is described in US Patent 4,611,891. Though decreasing overall production costs, this construction technique does not necessarily solve the need for adequate support for the individual reflective elements subject to weather, does not allow for reducing their weight, and does not 10 completely standardize the size of the construction elements used.

To provide a sufficient level of reliability, the support structure of reflectors built for outdoor use should desirably provide adequate support under normal operating conditions (for example when 15 repositioning) and protection under inclement weather without measurable deviation from the overall reflector shape. In addition, such a support structure should desirably be easily and inexpensively manufactured and assembled on site to avoid or minimise the use of special tools during on-site assembly and therefore allows easy 20 scalability. It should also be easily maneuvered when assembled (i.e. not excessively heavy).

25 **Summary of the Invention**

The present invention aims to provide a new and useful support structure for a reflector, the reflector using such a structure, and components for the structure.

Preferred embodiments of this invention are directed at a reliable support structure for supporting a reflector, which avoids or at least ameliorates the disadvantages of existing support structures for reflectors.

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In general terms, the present invention provides a support structure for supporting a reflector. The support structure comprises at least one section having one or more first contouring profiles having a pre-determined geometry and a plurality of support members for supporting at least one reflective element making up the reflector. Each of the support members comprises hinge means for coupling with an adjacent support member to form a common hinging axis and mounting means for mounting onto the first contouring profile. Upon mounting the support members onto the first contouring profile, adjacent support members are maintained at an angle with respect to their common hinging axis determined by the pre-determined geometry of the first contouring profile, so as to define the contour of the support structure according to the geometry of the reflector.

20 A first aspect of this invention is defined in claim 1. The contour of the support structure for a reflector is thus defined by the pre-determined geometry of the first contouring profile.

In a second aspect of the invention as defined in claim 20, there is provided a support member for supporting at least one reflective element.

In a third aspect of invention as defined in claim 25, there is provided a combination of a reflector system comprising the support structure

according to the first aspect of the invention and at least one reflective element making up a reflector.

5 In a fourth aspect of the invention as defined in claim 26, there is provided a method of assembling a support structure of a reflector using a first contouring profile having a pre-determined geometry, so that the support structure defines a contour according to the geometry of the reflector.

10 Preferred features of the invention have been defined by the dependent claims. In particular, multiple sections of the support structure of the reflector may be constructed using respective first contouring profiles. The multiple sections may be interconnected by at least one cross element having attachment means to one or more
15 first and/or second contouring profile(s), so as to define the overall contour of the support structure according to the geometry of the reflector.

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Brief Description of the Drawings

Preferred embodiments will now be described by way of example, with reference to the accompanying drawings, of which:

25 Figure 1, which composed Figures 1A-1D, illustrates a support member of a support structure;

Figure 2, which composed Figures 2A and 2B, illustrates adjacent support members of Figure 1 being interconnected;

Figure 3 illustrates a train of interconnected support members of Figure 2;

Figure 4 illustrates a contour formed by working surfaces of the interconnected support members of Figure 3;

Figure 5 illustrates the contour of Figure 4 being controlled by a first contouring profile;

5 Figure 6, which composed Figures 6A-6C, illustrates a cross element;

Figure 7 illustrates in side view four sections of the support structure interconnected by a second profile;

Figure 8 illustrates staggered sections of Figure 7;

10 Figure 9 illustrates three sections of the support structure comprising suspension elements and intermediate connecting elements;

Figure 10, which composed Figures 10A-10C, illustrates a particular suspension element of Figure 9;

15 Figure 11, which composed Figures 11A-11D, illustrates a particular intermediate connecting element of Figure 9;

Figure 12, which composed Figures 12A and 12B, illustrate a support member having non-essential openings;

20 Figure 13 illustrates a particular contouring profile being electrically controlled;

Figure 14, which composed Figures 14A-14C, illustrates the various retaining means of the support member of Figure 1 to retain at least one reflective element;

25 Figure 15, which composed Figures 15A-15C, illustrates a support member having a curved working surface;

Figure 16, which composed Figures 16A-16D, illustrate adjacent support members being interconnected by a snap-fit action.

Detailed Description of the Embodiments

The structure of each support member 101 making up the support structure is shown in Figures 1A-1D, which illustrate four projections of the support member 101. Each support member 101 comprises a working surface 103, a body 105, and hinge means (shown as interconnecting elements 107 having barrel-like structures). The working surface 103 features an integral channel 109, through which at least one reflective element (not shown) is introduced and retained. Further, the working surface 103 transfers its mechanical load (e.g. the weight of the reflective element and environmental loads like wind, precipitation and debris) to the body 105 as well as adjacent support members which are coupled or interconnected to the support member 101 via the interconnecting elements 107. The body 105 comprises two rectangular guide openings 111A, 111B for assembling multiple support members 101, so as to form the support structure for supporting the reflector. In particular, the two rectangular guide openings 111A, 111B are spaced apart by an offset distance ("X") measured between the centerlines of those openings. Because the structure of each support member 101 is identical or similar, its arrangement within the support structure is easily interchangeable.

The operation of the hinge means (i.e. the interconnecting elements 107) of each support member 101 is shown in Figures 2A and 2B. In particular, Figure 2A illustrates a pin 201 being inserted through the interconnecting elements 107 of the adjacent support members 101, while Figure 2B illustrates the adjacent support members 101 so interconnected by the pin 201. The hinge-like connection between the adjacent support members 101 therefore forms a common hinging axis 203, such that the adjacent support members 101, so

interconnected or hinged, pivotably rotate about the common hinging axis 203.

Figure 3 illustrates a train of four support members 101 which are interconnected, by using the pins 201, to make up a section of the support structure. (A section can also be formed by any other number of support members 101, so long as that number is more than one.) Accordingly, the degree of freedom between the adjacent support members 101 about their respective common hinging axes 203 allows the working surfaces 103 of these support members 101 to approximate a line of any required curve or geometry. Specifically, each working surface 103 of these support members 101 acts as a tangent to a line of desired geometry. Since the reflective elements are supported and retained on these working surfaces 103, a reflector formed by the reflective elements would therefore have a contour 401 in accordance with the line of desired geometry, as shown in Figure 4.

In constructing the support structure, its size is determined by the size of each support member 101 and also the size of the individual reflective elements which make up the reflector. As for constructing each support member 101, the ratio of its functional width (hereinafter: "FW") to its working surface width (hereinafter: "SW") is chosen such that the interconnected support members 101 provide sufficient support and retention to the reflective elements, whilst minimising the number of support members 101 used. At a minimum, each reflective element is supported and retained by a support member, whilst the maximum number of support members used is only limited by practical considerations. Typically, the width of each reflective element is about the same as SW.

To establish the shape of the section of the support structure, as defined by the working surfaces of the support members 101, a contouring profile 501 of a pre-determined geometry is inserted through the rectangular guide openings 111A, 111B of the support members 101, as shown in Figure 5. The contouring profile 501 prevents the support members 101 from pivotably rotating about their respective hinging axes 203. Because the adjacent support members 101 in the section of the support structure are maintained at an angle with respect to their respective common hinging axes, as determined by the contouring profile, the contour of the working surfaces 103 is thus defined by the pre-determined geometry of the contouring profile 501. As the reflective elements (making up the reflector) are supported and retained on these working surfaces 103, the section of support structure can therefore be constructed by interconnecting the support members 101 and then inserting the contouring profile 501 having that particular geometry through one of the guide openings 111A, 111B of each support member 101 to provide the appropriate working surface 103 for the reflector. The pre-determined geometry of the contouring profile 501, therefore, depends on its location in relation to the corresponding section of the support structure. This is because individual contouring profiles 501 define unique respective sections of the overall support structure of a required parabolic geometry. Accordingly, the geometry of the contouring profiles 501 is pre-determined in accordance with the shape of the reflector which the support structure supports. For parabolic reflectors which are symmetric about their axis (i.e. the line through the focal point and perpendicular to the directrix), the contouring profiles 501 which are closer to the centre of the support structure will tend to exhibit more curvature as compared with the

contouring profiles 501 which are arranged at the periphery of the support structure. However, for parabolic reflectors having vertices which do not appear on their surfaces at any point, the contouring profiles 501 at portions of such reflectors which are closest to the vertices will be more curved than other portions. Other factors which determine the geometry of the contouring profile may also include the application of a reflector.

Each contouring profile 501 is generally made from a rigid material which can be bent or molded easily to a pre-determined geometry, and which retains its shape after installation on to the corresponding section of the support structure. Preferably, each contouring profile 501 is made from steel or galvanised steel, but may also be made from aluminum alloy, ceramics, piezo alloy, or any other suitable metal. In addition, the choice of material may depend on certain properties (for example, thermal expansion and contraction coefficients) of the reflective material, and also on the required scale of the support structure and the associated safety considerations. A suitable dimension of a contouring profile 501 may, for example, measure 5 cm (about 2 inches) by 2.5 cm (about 1 inch) with regard to its cross-sectional area and having a wall thickness of about 0.32cm (about 0.13 inch), but other dimensions with the range may be equally suitable. Advantageously, each contouring profile 501 has a square or rectangular cross-section, so that the respective sections of the support structure are not prone to twisting or any movement. This ensures that the support structure defines the proper geometry of the reflector which it supports.

Further, Figure 5 shows the reflective elements being retained on the working surfaces 103 by spring-loaded retaining brackets 502, which

minimise the effects of thermal expansion and contraction whilst ensuring that the reflective elements remain on the working surfaces 103. In addition, a cross element 503 is also arranged along the contouring profile 501 so as maintain the position of a plurality of
5 sections of the support members making up the support structure.

Figures 6A-6C illustrate three projections of the cross element 503. Each cross element 503 is made of a suitable rigid material, which provides attachment means (i.e. two perpendicular openings (that is,
10 through-holes) 601, 603 for attaching to contouring profiles. The two perpendicular through-holes, which are identical in shape, size, and spaced apart by the offset ("X") of the two rectangular through guide openings 111A, 111B of the support member 101, as shown in Figures 6A and 6B. Each cross element 503 may be made from the
15 same material as the support structure or from steel, Aluminum alloy, ceramics, or any other suitable metal. However, cheaper alternatives may include plastics having UV degradation inhibitors and the necessary additives. Once the material of each cross element 503 is chosen, its dimension should be established such that the required
20 mechanical support for the reflector is provided adequately. The opening 601 of a particular cross element 503 receives the contouring profile 501 in relation to a corresponding section of the support structure. The other opening 603 (arranged along an axis perpendicular to that of the opening 601) receives another contouring
25 profile (not shown) of another pre-determined geometry, so that different sections of the support structure are maintained along that other contouring profile as required by the reflector having a particular geometry.

Accordingly, a number of support members 101 are interconnected by way of their hinge means to provide support for the reflective element to form a section of the support structure. Typically, the length of interconnected support members 101 within each section is within 1.8m (about 6 feet). Accordingly, each contouring profile 501, preferably measuring no longer than 1.8m is used to maintain adjacent support members 101 with respect to each other in each section. If required, multiple sections of the support structure can also be assembled together for supporting a reflector of a larger dimension, as shown in Figure 7.

Figure 7 shows a support structure having four sections (other embodiments may have different numbers), each section comprising three support members 101. These sections are connected together using a contouring profile 701 of a pre-determined geometry. The support structure so constructed for supporting the reflector therefore has geometry, as defined by the pre-determined geometries of the respective contouring profiles 501, 701 used in its construction and/or assembly.

Accordingly, by customising the pre-determined geometry of each contouring profile 501, 701, as determined by the required geometry of different reflectors, the support structure can achieve any practical geometry as dictated by the geometry of the reflectors which it defines and supports. Each contouring profile 501, 701 may have a circular, triangular, rectangular, or any polygonal cross-section of sufficient mechanical strength that can be sufficiently controlled when preparing its curvature, depending on the specific application and the material used. Preferably, however, each contouring profile 501, 701 has a rectangular cross-section with a length to width ratio of 2:1.

Generally, the size and proportions of support members 101 are chosen to provide sufficient, balanced mechanical support to the individual reflective elements. Practically, an integer number of support members 101 would be interconnected in the above described manner, so that the overall dimensions of the support structure are equal or slightly larger than the dimensions of the reflector which it supports. The support structure is then affixed to a base structure by mechanical means, including but not limited to channels, brackets, springs, adhesives, etc. Preferably, each contouring profile 501 associated with a corresponding section of the support structure attaches to the base structure using a minimal number of attachment points (e.g. two attachment points) so as to minimise deflection of the contour of the support structure due to differences in thermal expansion/contraction or facilitate the employment of piezoalloys for fine tuning. The use of non-permanent fasteners allows structure disassembly, if needed at any time thereafter.

In another embodiment, shown on Figure 8, the four sections of the support structure are arranged in a staggered formation, allowing portion of the oncoming wind to pass through the small gaps formed by offset mounting of every other section so that reflective elements in each section lie in a plane behind or in front of the plane of its immediate neighbor, offset at a distance X, which is the same as the offset distance X between the two rectangular guide openings 111A, 111B of each support member 101.

To achieve this staggered formation, the contouring profiles 501 used for these sections are inserted through the upper and the lower

rectangular guide openings 111A, 111B of the support members 101 of each section in an alternate fashion.

5 This arrangement provides for a reduced overall wind load borne by the reflector. It should be noted that the shapes of the contouring profiles used to assemble these staggered sections significantly differ in their target focal distance, designed to ensure that the focal lines of all staggered sections coincide. In the case of a reflector exhibiting a general parabolic shape, this stipulation means that the reflector is
10 essentially comprised of two or more separate paraboloid sections with coinciding foci.

The same principle can be applied in yet another embodiment shown in Figure 9, where three sections of the support structure are
15 arranged in a staggered formation. The support members 101 of any one section are interconnected and thus aligned with respect to one another. As shown in Figure 9, the contouring profiles 501 of the two outer sections extend to reach the first support members 101 at the flanks of the middle section to fix the relative position between that
20 middle section and the two outer sections. The offset distance between each of the outer section and the middle section is equal to the distance "X" between the guide openings 111A, 111B of each support member 101.

25 In this example, the interconnecting elements 107 of the two end support members 101 between the adjacent sections are connected to an intermediate connecting element 901, by way of a connecting pin in a manner similar to the interconnection between any two adjacent support members 101 of each section. A suspension
30 element 903 is then used to affix the section to the base structure.

Advantageously, the suspension element 903 ensures proper alignment between adjacent sections, and further provides lateral support for the support structure. However, this is an optional feature of the support structure since the support structure may be integral
5 with the base structure.

Figures 10A-10C show three projections of the suspension element 903. When used, the suspension element 903 is connected to the base structure by common bolt and nut assemblies or screws through
10 the appropriate openings 1001 to provide additional weight carrying capability. In particular, the suspension element 903 has hinges 1003 which interconnect with the support members 101 and the base structure by way of a connecting pin (not shown) , being similar or identical to the pin 201 as shown in Figure 2.

15 The intermediate connecting element 901, shown in Figures 11A-11D, comprises three hinges 1101 identical to those of the support elements 101 and the suspension element 903. At least two of the hinges 1101 are spaced apart by a distance "X", which is the same as
20 the offset distance between the guide openings 111A, 111B of each support member 101.

Preferably, the support member 101 is made from polymer, but any material with sufficient performance in the target environment can be
25 used instead. To save material, or when needed in the manufacturing process, the body of the support member 101 may be designed such that a plurality of non-essential openings 1201 reduces its weight/cost without compromising its overall strength or affecting its intended function. Such an implementation of the support member
30 1200 is shown in Figure 12.

Figure 13 illustrates an operation to control the curvature of the contouring profile 501. (Similar operations can also apply to the contouring profile 701) Piezo alloy may be incorporated along the length of the contouring profile 501 in a manner such that, when voltage potential (provided by a voltage source 1301) is applied at its ends, the resulting mechanical deflection will provide fine-tuning capability to the corresponding support members 101.

- 10 The amount of deflection (D) depends on the element size and material, and the applied voltage. A simple controller may be employed to control the contouring profile 501 to ensure precise focusing remote control. This technique may be used for controlling the amount of energy delivered to the reflector's focal area, within limits set by the size and curvature of the reflector, contouring profiles 501, 701, and type of the piezo alloy used in their manufacture.

Alternatively, the base member 101 may be designed without the integral channels 109 used for retention of the reflective elements in the preferred embodiment. Instead, the reflective elements may be securely retained to the working surfaces 103 by any means deemed appropriate and adequate for the target application: suitably shaped clip-on brackets 1401 (as shown in Figure 14A), screwed-in brackets 1403 (as shown in Figure 14B), retention springs/clips 1405 (as shown in Figure 14C), vacuum suction cups, adhesive tape, or any other suitable means of securely retaining the reflective element or portion thereof to the working surfaces 103 of each employed base member 101.

In another embodiment, the working surface 1501 is curved to achieve better reflector curve approximation. Such shaping may be vertical, horizontal, or both, as shown in Figure 15, and is particularly useful when working with a thinner reflective element material. Such
5 shaping of the working surface 1501 customises the support member 101 to make it more suitable for a given application than others. Like the previous embodiments, the working surface 1501 in this embodiment also includes an integral channel 1502 through which at least one reflective element (not shown) is introduced and retained,
10 except that the integral channel 1502 is curved.

In yet another embodiment, the adjacent support members 101 are interconnected by snap-on hinges 1601, as shown in Figure 16, instead of a pin. The suspension elements 903 and the intermediate
15 connecting elements can also be designed to include such snap-on hinges 1601.

Thus, although the invention has been described using preferred embodiments, many variations are possible within the scope of the
20 claims, as will be clear to the skilled reader, without departing from the invention as claimed. For example, the support member in each section may be clamped to the corresponding profile, instead of a body projected from its working surface and having openings in that body for introducing and
25 retaining the profile.

Claims

1. A support structure for supporting a reflector, the support structure having at least one section comprising:

5 a first contouring profile having a first pre-determined geometry; and

a plurality of support members for supporting at least one reflective element to make up the reflector, each of the plurality of support members comprising:

10 a support portion for supporting the at least one reflective element;

hinge means for coupling with an adjacent support member to form a common hinging axis; and

mounting means for mounting on to the first contouring profile,

15 whereby upon mounting the plurality of support members on to the first contouring profile, adjacent support members are maintained at an angle with respect to their common hinging axis, as determined by the first contouring profile, to define the contour of said support portions for supporting the at least one reflective element.

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2. The support structure of claim 1, wherein the mounting means comprises a member projecting from said support portion, the member comprising at least one guide opening for receiving the first contouring profile.

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3. The support structure of claim 1 or claim 2, wherein the at least one section comprises at least one cross element having attachment means for attaching to the first contouring profile and to at least one further contouring profile.

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4. The support structure of claim 3, wherein the attachment means includes a first through-hole to receive in a first direction the first contouring profile.
- 5 5. The support structure of claim 3 or claim 4, wherein the attachment means attaches to a second contouring profile having a second pre-determined geometry.
6. The support structure of claim 5, wherein the attachment
10 means includes a second through-hole to receive in a second direction the at least one further contouring profile.
7. The support structure of claim 5 or claim 6, wherein a plurality of said sections are arranged along the at least one further
15 contouring profile, so as to define the contour of said support portions.
8. The support structure of claim 7, wherein the plurality of said sections are arranged such that an edge of one section is spaced apart from a corresponding edge of an adjacent section.
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9. The support structure of any of the preceding claims, further comprising an interconnecting element having hinge means for coupling adjacent sections of the support structure.
- 25 10. The support structure of any of the preceding claims, wherein the respective pre-determined geometry of the first or the at least one further contouring profile is controllable by an applied voltage.

11. The support structure of claim 10, wherein at least one of the first or the at least one further contouring profile, or part thereof, is made of piezo alloy.
- 5 12. The support structure of claim 10 or claim 11, further comprising a controller to monitor and control changes to the respective pre-determined geometry.
- 10 13. The support structure of any of the preceding claims, wherein the hinge means for coupling each support member with the adjacent support member in each said one section includes a hinge-and-pin arrangement
- 15 14. The support structure of any of claims 1 to 12, wherein the hinge means for coupling each support member with the adjacent support member in each said section includes a snap-on arrangement.
- 20 15. The support structure of any of the preceding claims, wherein said support portion of each support member is curved.
16. The support structure of any of the preceding claims, wherein said support portion of each support member comprises means for retaining the reflective element.
- 25 17. The support structure of claim 16, wherein the means for retaining the reflective element includes any one of the following selected from a group comprising: a bracket; a spring; a clip; a cup; and adhesives.

18. The support structure of any of the preceding claims, wherein each support member is made of polymer.
19. The support structure of any of the preceding claims, further comprising a suspension element having hinge means for coupling each said section to a base structure.
20. A support member for supporting at least one reflective element, the support member comprising:
- hinge means for coupling with an adjacent support member to form a common hinging axis; and
- mounting means for mounting on to a contouring profile having a pre-determined geometry.
21. The support member of claim 20, wherein the mounting means comprises a member having at least one guide opening for receiving the contouring profile.
22. The support member of claim 20 or claim 21, further comprising a support portion for supporting the at least one reflective element.
23. The support member of claim 22, wherein said support portion comprises means for retaining the at least one reflective element.
24. The support member of claim 23, wherein the means for retaining the at least one reflective element includes any one of the following selected from a group comprising: a bracket; a spring; a clip; a cup; and adhesives.

25. A reflector system comprising at least one reflective element making up a reflector, and the support structure of claims 1 to 19 for supporting the reflector.
- 5 26. A method of assembling a support structure for supporting a reflector, the support structure comprising at least one section having a plurality of support members for supporting at least one reflective element to make up the reflector, each of the plurality of support members having a support portion for supporting the at least one
10 reflective element, the method comprising the steps of:
coupling each support member with an adjacent support member to form a common hinging axis; and
mounting the plurality of support members on to a first contouring profile having a first pre-determined geometry,
15 so that adjacent support members are maintained at an angle with respect to their common hinging axis, as determined by the first contouring profile, to define the contour of said support portions for supporting the at least one reflective element.
- 20 27. The method of claim 26, wherein the mounting of the plurality of support members onto the first contouring profile comprises introducing the first contouring profile through a guide opening of a member projecting from each support member.
- 25 28. The method of claim 26 or claim 27, further comprising the step of attaching at least one cross element to the first contouring profile.
29. The method of claim 28, wherein the attaching of the at least one cross element to the first contouring profile includes introducing

the first contouring profile in a first direction into a first through-hole of the at least one cross element.

30. The method of claim 28 or claim 29, further comprising the step
5 of attaching the at least one cross element to a second contouring profile having a second pre-determined geometry.

31. The method of claim 30, wherein the attaching of the at least
one cross element to the second contouring profile includes
10 introducing in a second direction the second profile into a second through-hole of the at least one cross element, so as to define the contour of said support portions for supporting the reflective elements.

15 32. The method of any of claims 26 to 31, wherein the coupling of each support member with the adjacent support member includes introducing a pin through respective hinges of the support member and said adjacent support member.

20 33. The method of claims 26 to 31, wherein the coupling of each support member with the adjacent support member includes snapping of respective hinges of the support member and said adjacent support member.

25 34. The method of claims 26 to 33, further comprising the step of threading the at least one reflective element on to the plurality of support members.

35. The method of claims 26 to 34, further comprising the step of retaining the at least one reflective element on said support portion of each support member.

- 5 36. The method of claim 35, wherein the retaining of the reflective element on said support portion includes using any one of the following selected from a group comprising: a bracket; a spring; a clip; a cup; and adhesives.