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(54) SUSPENSION SUPPORT SYSTEM FOR
MOVEMENT OF A LOAD THEREALONG

71) I, GERHARD MULLER, a Swiss subject, of Zipfelwiesenstrasse 7, Dietlikon, Switzerland, do hereby declare the invention for which I pray that a patent may be granted to me and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to suspension support systems for movement of loads therealong and in particular, although not so restricted, to cable car systems, cableways or aerial tramways.

U.K. patent specification No. 1,364,555 discloses a suspension and carrier system which is so arranged that the support or catenary cable is not relaxed or tension-released when a movable load is removed, so that the maximum loading of the catenary cable which arises when the movable load is intermediate of a tension zone subject to tension, is approximately the same as that in the remaining tension zones without any movable load thereat. In order to obtain this condition, which may be termed pre-stressing, or pre-loading of the catenary cable, the carrier cable on which the load actually is supported must be substantially pre-stressed. Practically it is necessary to form the carrier cable of at least two cable elements, or ropes (such as, for example, steel ropes) which have about double the cross-sectional area and double the tensile strength of the catenary cable. As the tension in the carrier cable increases, the differences in sag between the carrier cable upon presence or absence of a load become less. The movable load, if a single load, is distributed over a greater region of the tension zone when the carrier cable tension itself is increased. Pre-loading or pre-stressing of the support cable is then obtained when connecting elements or spacers within any tension zone transfer a distributed load formed by the average

weight of the movable load plus the proportion of the weight of the connecting element or spacer itself and the apportioned weight of the carrier cable. As a consequence, pylons supporting the cables must be so constructed that they provide a downwardly directed force on the carrier cable, that is, to press the carrier cable downwardly. This is explained in detail in the U.K. patent specification No. 1,364,555.

Basically, the suspension support system disclosed in this U.K. patent specification includes a plurality of pylons on which a catenary or support cable is supported and a tensioned carrier cable is, in turn, supported by spacers or hangers from the catenary cable. The spacers are so dimensioned that the carrier cable is held in an upwardly bowed, or upwardly curved condition so that, upon loading by the movable load, the carrier cable will flatten out or stretch to be essentially flat. The tension of the carrier cable is at least twice the tension in the catenary cable; the sum of all the tensions or forces in the spacers between two adjacent pylons is approximately equal to the weight of the carrier cable and the average load carried thereon. The force required to hold the carrier cable down, applied at the pylons, corresponds approximately to the average movable load.

The suspension support system, as described in U.K. patent specification No. 1,364,555 thus provides an arrangement in which, due to pre-stressing of the catenary cable, up to about 75% of the sag and tension differences arising in suspension systems of the prior art could be eliminated. The remaining sag had to be accepted and had to be compensated by a stiff pylon or support construction; otherwise, when using self-aligning or self-adjusting supports or swing supports, a relative longitudinal displacement or shift

between the carrier cable and the catenary cable arose in adjacent zones between adjacently located pylons. This longitudinal shift between the cables became additive; the sag in the catenary cable was increased by loading the carrier cable, requiring additional cable length; simultaneously, the rise, that is the upwardly directed bowing of the carrier cable, decreased. Keeping the carrier cable tension constant, an increase in the length thereof resulted. This longitudinal shift, due to the tension relationships, had as a result that the normally vertical hangers change to an inclined direction; distributed over a plurality of zones between the pylons, the tension equalized, and the relative shift of the cable also decreased. It is difficult to express this change in vertical position of the spacers, and the shift in length of the cable in mathematical terms. The situation is further impaired when the suspension support system is long and supports a plurality of movable loads.

The present invention seeks to provide a suspension support system, in which relative longitudinal displacement or shift between a catenary or support cable and a carrier cable is essentially eliminated.

According to one aspect of the present invention there is provided a suspension support system for movement of a load therealong comprising: a plurality of pylons; a support cable supported on the pylons; tensioned carrier cable means on which the load is suspended for movement along the carrier cable means whilst being supported thereby, said carrier cable means including two individual cable elements; cross-ties connecting the cable elements in spaced apart relationship whereby the two cable elements form a trackway, connecting rods located intermediate the cable elements, each rod interconnecting two adjacent cross ties, the connecting rods being pivotally connected to said cross ties, spacers supporting the carrier cable means from the support cable by virtue of pivotal connection of the spacers to the connecting rods to support said connecting rods and hence support said cross ties and trackway, said spacers being dimensioned to maintain the carrier cable means in upwardly bowed condition when unloaded, and to assume an approximately straight or level state when loaded by the load, the tension in the carrier cable means being at least twice the tension in the support cable, the support cable, carrier cable means and spacers being so tensioned and arranged that, in side view, the curve formed by the support cable and the curve formed by the carrier cable means touch each other midway between each adjacent pair of pylons to provide for equalization of tension therein; a

respective force equalization plate located midway between each adjacent pair of pylons; and clamping means securing the support cable and carrier cable means to said force equalization plate thus to interconnect the support cable and the carrier cable means to prevent relative longitudinal displacement therebetween.

According to another aspect of the present invention there is provided a suspension support system for movement of a load therealong comprising: a plurality of pylons; a support cable supported on the pylons; a tensioned carrier cable means on which the load is suspended for movement along the carrier cable means whilst being supported thereby said carrier cable means including two cable elements located adjacent each other, a trackway over above the cable elements to form a running surface for the load to operate therealong; a resilient intermediate layer between the trackway cover and the cable elements; spacers supporting the carrier cable means from the support cable, said spacers being dimensioned to maintain the carrier cable means in upwardly bowed condition when unloaded, and to assume an approximately straight or level state when loaded by the load, the thickness of the intermediate layer varying along its length and being arranged to compensate for sag of the cable elements between the spacers, the tension in the carrier cable means being at least twice the tension in the support cable, the support cable, carrier cable means and spacers being so tensioned and arranged that, in side view, the curve formed by the support cable and the curve formed by the carrier cable means touch each other midway between each adjacent pair of pylons to provide for equalization of tension therein; a respective force equalization plate located midway between each adjacent pair of pylons, and clamping means securing the support cable and carrier cable means to said force equalization plate thus to interconnect the support cable and the carrier cable means to prevent relative longitudinal displacement therebetween.

Arranging the cables as aforesaid simplifies the static positioning of the cables and renders it more precise. The pylons may be constructed with lesser height — given a predetermined height of the carrier cable above ground level — and the spacers need no longer be constructed to permit slanting thereof. Their lower connection no longer requires ball joints. The entire suspension support system has a slimmer appearance, the surface subject to wind loading is decreased. The length of the cableway no longer has any influence on the static or dynamic behaviour of the

cable supports; more than one movable load can be supported by the carrier cables at any zone, between pylons.

The invention is illustrated, merely by way of example in the accompanying drawings, in which:—

Figures 1, 2 and 3 correspond substantially to Figures 1, 2 and 3 of U.K. patent 1 364 555 and illustrate:

10 In Figure 1 a side view showing the principal tension relationships in a support cable and carrier cable, Figure 2 the tension relationships having a support cable, a carrier cable and a hanger system, with a load attached, in a suspension bridge arrangement, and Figure 3 a suspension support system;

Figure 4 is a highly schematic representation, in side view, of the suspension support system according to the present invention;

Figure 5 is a part sectional, part perspective view to a greatly enlarged scale, of an equalization plate of a suspension support system according to the present invention;

Figure 6 is a perspective, schematic view of a flexible trackway for the system of Figure 4; and

Figure 7 is a part sectional, part perspective view of a flexible track connection to a cross tie, to a greatly enlarged scale, and showing a fragment of the arrangement of Figure 6.

Referring first to Figure 1, a support system is supported by pylons 3 on which a support or catenary cable 1 is suspended which, in turn, supports a carrier cable 2 forming the actual trackway or driveway for the load, and on which a load is movable. The region between the end points and the next adjacent pylon, and the region between the pylons 3 themselves, are designated herein as span zones. In unloaded condition, the support or catenary cable 1 has little tension therein. The catenary cable 1, thus, has substantial sag or hang-through in the span zones. The carrier cable 2, however, has only little sag when unloaded and is subjected to high tension. Except for the tension, the weight of the support cable as well as the weight of the carrier cable is fully accepted by the pylons 3.

Connecting elements, that is, hangers or spacers 4 support, as seen in Figure 2, the carrier cable 2 on the cable 1. No forces from the carrier cable 2 will arise on the pylons 3 when the carrier cable 2 is in unloaded condition. This is the general condition in suspension bridges and, in general, in overhead or trolley or catenary systems in main line electric railways. If, then, a movable load 5 is placed on the carrier cable 2, the catenary cable 1 as

well as the carrier cable 2 will sag in the respective span zone, as clearly seen in Figure 2. The weight of the load 5 then must be accepted by the adjacent pylons 3'. To provide for the sag, the carrier cable 2 is pulled over from adjacent span zones which, as previously noted, causes damage to the cable and slanting or skewing of the spacers 4.

A suspension support system is illustrated in Figure 3. In this system the spacers 4 are so arranged that they pull the carrier cable 2 and the catenary cable 1 towards each other, while the carrier cable 2, itself, is maintained under substantial tension. The forces are so arranged that the sum of the tensions in all the spacers 4 between adjacent pylons is substantially equal to the weight of the carrier cable (and such additional structure as may be associated therewith) plus the weight of the average load. As a result, upwardly directed forces will arise at the pylons 3" corresponding approximately to the average movable load. These upwardly directed forces must be accepted by holding systems to press the carrier cable 2 downwardly.

The customarily used structures correspond, essentially, to the suspension bridge arrangements in which the pylons do not, however, have to transmit hold-down forces. The pylons need not transfer any upwardly directed forces, that is, to hold bowed elements down, and the catenary cables have to transfer only the weight of the roadway or other surface, even if the roadway is upwardly bowed when empty of traffic thereover.

The upward bowing or rise of the carrier cables upon a distributed traffic load becomes less as the tension in the cables is increased. In practical arrangements, the tension in the carrier cable should be at least twice the maximum tension in the catenary cable 1.

If a movable load 5 is placed on the system of Figure 3, then a relatively small increase in the tension of the catenary cable 1 causes drop or sag of the carrier cable 2. The tension previously applied to the catenary cable 1 corresponding to the weight of the movable load, in addition to the weight of the carrier cable 2 itself is now eliminated, and is replaced by the actual load. This, however, unloads the pylons 3". If the actual weight of the movable load is equal to the average weight then, under a pylon 3", the weight due to the load actually will be zero. In contrast to the known constructions, therefore, passing of a load across a pylon will not be noticed at all.

The foregoing arrangement of the catenary cable and of the carrier cable per-

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mitted elimination of the previously noted sag and tension differences up to 75% thereof. In accordance with the present invention, and to further improve the tension relationships and the running smoothness of movable loads, the catenary cable and the carrier cable are so arranged that, looked at in side view, the cables touch each other midway between each adjacent pair of pylons. At these touching points or zones, force equalization plates are provided, as explained in connection with Figures 4 and 5.

A suspension support system according to the present invention is shown in Figure 4 and is sub-divided into four span zones. At contact points B, the catenary cables 1 and the carrier cables 2 are at the same elevation.

A force equalization plate 13 is shown in Figure 5, by way of example. Such a plate may be applied at the points B (Figure 4) centrally within the span zones. Plate 13 is suitably grooved to accept the various cable or rope elements of the catenary cable 1 and the carrier cable 2. The catenary cable 1 is formed of two cable elements 1a, 1b, located and running parallel to each other. At the edges of the plate 13, two each carrier cable elements 2a, 2b, 2'a, 2'b are located. The various cable elements are clamped in conventional manner, that is, the cable elements 1a, 1b are secured by means of a clamping plate 14 and clamping bolts 15 passing there-through. The cable elements of the carrier cables 2 should have top surfaces engageable by wheels or sheaves of the movable load and, therefore, they are located in milled grooves in the plate 13, and held in position by means of wedges 16 which are secured by means of screws 17 to plate 13, to clamp the cable elements of the cable 2 to the plate 13.

Figure 6 illustrates two pairs of cable elements 21, 21' forming a carrier cable covered by a trackway cover providing running surface 22, 22' respectively, to form suspended tracks. The curvature of the edges of the cover providing the running surface is smaller than the radius of curvature of the cable elements. The cable elements 21, 21' are secured at suitable distances to cross ties 23, similarly to the attachment of the cable elements 2a, 2b, to the plate 13 (Figure 5). The cable elements 21, 21' may also be attached to other suitable surfaces, such as rigid cross ties, for example adjacent termination of the suspension system. A resilient layer 24 (Figure 7), for example, of plastics material is located between each cable element and the cover forming the surface 22, 22'. This cover may be of metal, such as steel, or of plastics material. The thickness of the in-

intermediate resilient layer 24 varies. In the region of the cross ties 23 and spacers 25, the layer 24 is comparatively thin, having a dimension d (Figure 7). In the region intermediate two cross ties 23 or spacers 25, respectively, the thickness of the resilient layer 24 increases, to a dimension D (Figure 6). The layer 24, when unloaded, therefore provides for slight super-elevation of the running surface formed by the surface 22.

The surface 22, 22' is secured to the cross ties 23 by means of screws or rivets 26 (Figure 7). The cross ties 23 are pivotally attached to a rod 27 which has some resiliency, and which, in turn, is pivoted to the spacers 25, as clearly seen in Figure 6. The surface 22, 22' is also connected to the respective cable elements 21, 21' intermediate the attachment to the cross ties, as seen in Figure 6, for example by utilizing a wedge similar to the wedge 16 (Figure 5). The attachment of the flexible trackway formed of the cable elements 21, 21' and the surface 22, 22' to a cross tie is best seen in Figure 7. Using two cable elements to form a pair, rather than a cable of equal cross-sectional area, has substantial advantages in original manufacture, assembly and transport for installation. An additional and substantial advantage is the increased flexibility of the trackway, since the torsion forces caused by pressure of the wheels or rollers passing thereover, and on which the load is suspended, are decreased. It is also possible to secure the individual cable elements with respect to all directions without interfering with the profile of the trackway on which the rollers or wheels of the movable load have to operate.

The cross ties 23 and the rod 27 are secured to one another at a pivot connection above the centre line CL of the cross ties, as seen at 30 (Figure 6) where the cross ties are positively (that is upwardly) loaded. If the loading changes between positive and negative directions (that is, vertically upwardly or downwardly, respectively), then the pivot connection is preferably located at substantially the same level as a centre line 31, Figure 6; if the loading is clearly always in the downward direction, then the pivot connection is preferably below the centre line, as illustrated at 32, Figure 6.

The surface 22, 22' is extended over the edge of the cable elements 21, 21', respectively, and is domed or bowed in cross section. This improves the guidance of the wheels or rollers of the movable load. The surface 22, 22' can also be covered with friction increasing or friction decreasing coating or other applied material, such as, for example, sand 35, particularly at those

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points where the movable load is to be braked. The space between the individual cable elements 21, 21' can be electrically heated by introducing heating wires 36.

5 The narrowest point between the cable elements is formed with a seal 37 to protect the heating wires. The surface 22, 22', and particularly when extended over both cable elements of the cable pairs and

10 domed, substantially improves the running smoothness of a movable load; the partial pressure of the wheels on the surface is reduced, as are losses due to friction and flexing of the cable elements 21, 21'. Heat-

15 ing of the cables upon passing of the movable load over a particular point is also decreased. The top of the cable elements is protected; below this protec-

20 tion, and due to the relatively wide track surface, electrical insulation material can be applied, and additional wires, such as electrical power supply or control wires for the movable load can be attached. The same profile of the running surface can

25 also be used for rigid track sections, for example in curves, for track switches, stations, sidings, or track sections, or on fixed rigid constructions without a cable, and to which the cable suspension is joined.

30 The layer 24 is preferably adhered to the cover providing the surface 22, 22' before being covered; the cable elements 21, 21' are coated, for example by painting, with a rust-preventive paint. It is necessary to per-

35 mit removal of the surface 22, 22', at least in part, in order to permit checking of the integrity of the cables and the cable elements. A quick and ready check can be effected, without the laborious removal of

40 the surface 22, 22', by painting each of the cable elements with a control strip at the position marked x (Figure 7). If any wires should break, the cable will shift position; this shift may be in the order of about 1

45 cm. This shift results in a well visible and clearly observable break of the painted strip, even if the break point itself is hidden beneath the surface 22, 22'. The sur-

50 face 22, 22' is not stressed under tension, or only insignificantly so; for ease of assembly it is preferred to make them in rather short lengths, for example about the distance between spacers 25 as shown. To

55 provide for smooth running of the rolling load, the joints do not extend transversely to the cable elements 21, 21' but rather extend at an angle of, for example, 30° to 45° with respect to the longitudinal axis of the cable, leaving a small gap similar to an

60 expansion joint.

The layer 24 is not strictly necessary; it is also not necessary to form the layer 24, if used, with a varying thickness; if used, strips having different thicknesses, or other

65 supports between the cable elements 21,

21', respectively, and the surface 22, 22' can be used, the increase in thickness being so arranged to compensate for sag or hang-through of the cable between the hangers.

WHAT WE CLAIM IS:

1. A suspension support system for movement of a load therealong comprising: a plurality of pylons; a support cable means whilst being supported

75 carrier cable means on which the load is suspended for movement along the carrier cable means whilst being supported thereby, said carrier cable means including

80 two individual cable elements; cross ties connecting the cable elements in spaced apart relationship whereby the two cable elements form a trackway, connecting rods located intermediate the cable elements,

85 each rod interconnecting two adjacent cross ties, the connecting rods being pivotally connected to said cross ties, spacers supporting the carrier cable means from the support cable by virtue of pivotal connection of the spacers to the connecting

90 rods to support said connecting rods and hence support said cross ties and trackway, said spacers being dimensioned to maintain the carrier cable means in upwardly bowed condition when unloaded, and to assume

95 an approximately straight or level state when loaded by the load, the tension in the carrier cable means being at least twice the tension in the support cable, the support cable, carrier cable means and spacers

100 being so tensioned and arranged that, in side view, the curve formed by the support cable and the curve formed by the carrier cable means touch each other midway between each adjacent pair of pylons to

105 provide for equalization of tension therein; a respective force equalization plate located midway between each adjacent pair of pylons; and clamping means securing the support cable and carrier cable means

110 to said force equalization plate thus to interconnect the support cable and the carrier cable means to prevent relative longitudinal displacement therebetween.

2. A suspension support system for

115 movement of a load therealong comprising: a plurality of pylons; a support cable supported on the pylons; a tensioned carrier cable means on which the load is suspended for movement along the carrier

120 cable supported on the pylons; a tensioned said carrier cable means including two cable elements located adjacent each other, a trackway cover above the cable elements to form a running surface for the load to

125 operate therealong; a resilient intermediate layer between the trackway cover and the cable elements; spacers supporting the carrier cable means from the support cable, said spacers being dimensioned to maintain

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points where the movable load is to be braked. The space between the individual cable elements 21, 21' can be electrically heated by introducing heating wires 36.

- 5 The narrowest point between the cable elements is formed with a seal 37 to protect the heating wires. The surface 22, 22', and particularly when extended over both cable elements of the cable pairs and
10 domed, substantially improves the running smoothness of a movable load; the partial pressure of the wheels on the surface is reduced, as are losses due to friction and flexing of the cable elements 21, 21'. Heat-
15 ing of the cables upon passing of the movable load over a particular point is also decreased. The top of the cable elements is protected; below this protection, and due to the relatively wide track
20 surface, electrical insulation material can be applied, and additional wires, such as electrical power supply or control wires for the movable load can be attached. The
25 same profile of the running surface can also be used for rigid track sections, for example in curves, for track switches, stations, sidings, or track sections, or on fixed rigid constructions without a cable, and to which the cable suspension is joined.

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35 mit removal of the surface 22, 22', at least in part, in order to permit checking of the integrity of the cables and the cable elements. A quick and ready check can be effected, without the laborious removal of
40 the surface 22, 22', by painting each of the cable elements with a control strip at the position marked x (Figure 7). If any wires should break, the cable will shift position; this shift may be in the order of about 1
45 cm. This shift results in a well visible and clearly observable break of the painted strip, even if the break point itself is hidden beneath the surface 22, 22'. The surface 22, 22' is not stressed under tension, or only insignificantly so; for ease of as-
50 sembly it is preferred to make them in rather short lengths, for example about the distance between spacers 25 as shown. To provide for smooth running of the rolling
55 load, the joints do not extend transversely to the cable elements 21, 21' but rather extend at an angle of, for example, 30° to 45° with respect to the longitudinal axis of the cable, leaving a small gap similar to an
60 expansion joint.

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65 supports between the cable elements 21,

21', respectively, and the surface 22, 22' can be used, the increase in thickness being so arranged to compensate for sag or hang-through of the cable between the hangers.

WHAT WE CLAIM IS:

1. A suspension support system for movement of a load therealong comprising: a plurality of pylons; a support cable means whilst being supported
75 carrier cable means on which the load is suspended for movement along the carrier cable means whilst being supported thereby, said carrier cable means including two individual cable elements; cross ties
80 connecting the cable elements in spaced apart relationship whereby the two cable elements form a trackway, connecting rods located intermediate the cable elements, each rod interconnecting two adjacent cross
85 ties, the connecting rods being pivotally connected to said cross ties, spacers supporting the carrier cable means from the support cable by virtue of pivotal connection of the spacers to the connecting
90 rods to support said connecting rods and hence support said cross ties and trackway, said spacers being dimensioned to maintain the carrier cable means in upwardly bowed condition when unloaded, and to assume
95 an approximately straight or level state when loaded by the load, the tension in the carrier cable means being at least twice the tension in the support cable, the support cable, carrier cable means and spacers
100 being so tensioned and arranged that, in side view, the curve formed by the support cable and the curve formed by the carrier cable means touch each other midway between each adjacent pair of pylons to
105 provide for equalization of tension therein; a respective force equalization plate located midway between each adjacent pair of pylons; and clamping means securing the support cable and carrier cable means
110 to said force equalization plate thus to interconnect the support cable and the carrier cable means to prevent relative longitudinal displacement therebetween.

2. A suspension support system for movement of a load therealong comprising: a plurality of pylons; a support cable supported on the pylons; a tensioned carrier cable means on which the load is
120 suspended for movement along the carrier cable supported on the pylons; a tensioned said carrier cable means including two cable elements located adjacent each other, a trackway cover above the cable elements to form a running surface for the load to
125 operate therealong; a resilient intermediate layer between the trackway cover and the cable elements; spacers supporting the carrier cable means from the support cable, said spacers being dimensioned to maintain
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- the carrier cable means in upwardly bowed condition when unloaded, and to assume an approximately straight or level state when loaded by the load, the thickness of the intermediate layer varying along its length and being arranged to compensate for sag of the cable elements between the spacers, the tension in the carrier cable means being at least twice the tension in the support cable, the support cable, carrier cable means and spacers being so tensioned and arranged that, in side view, the curve formed by the support cable and the curve formed by the carrier cable means touch each other midway between each adjacent pair of pylons to provide for equalization of tension therein; a respective force equalization plate located midway between each adjacent pair of pylons; and clamping means securing the support cable and carrier cable means to said force equalization plate thus to interconnect the support cable and the carrier cable means to prevent relative longitudinal displacement therebetween.
3. A system as claimed in claim 2 in which said layer is secured to the trackway cover providing the running surface but not to the cable elements.
4. A system as claimed in claim 2 or 3 in which the running surface consists of unitary elements extending between the spacers, the joints between adjacent unitary elements forming a small gap and being inclined with respect to both the transverse and the longitudinal direction of the carrier cable means.
5. A system as claimed in any of claims 2 to 4 including a surface coating on selected zones of the running surface.
6. A system as claimed in any of

claims 2 to 5 including sealing means located between the cable elements, and heating means located in the sealed space between the sealing means and the cover providing the running surface.

7. A system as claimed in any of claims 2 to 6 in which the upper surface of the trackway cover providing the running surface is bowed or domed, and the edges thereof are rounded.

8. A system as claimed in claim 7 in which the radius of curvature of the edges of the trackway cover providing the running surface is smaller than the radius of curvature of the cable elements.

9. A system as claimed in claim 1 in which the connecting point between the cross ties and each connecting rod is located with respect to the centre line of the cable elements so that with upwardly directed loading of the cross ties, the connecting point is above the centre line of the cable elements, with downwardly directed loading of the cross ties the connecting point is below the centre line of the cable elements, and with variable upwardly and downwardly directed loading of the cross ties the connecting point is at substantially the same level as the centre line of the cable elements.

10. A suspension support system for movement of load therealong substantially as herein described with reference to and as shown in Figures 4 to 7 of the accompanying drawings.

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