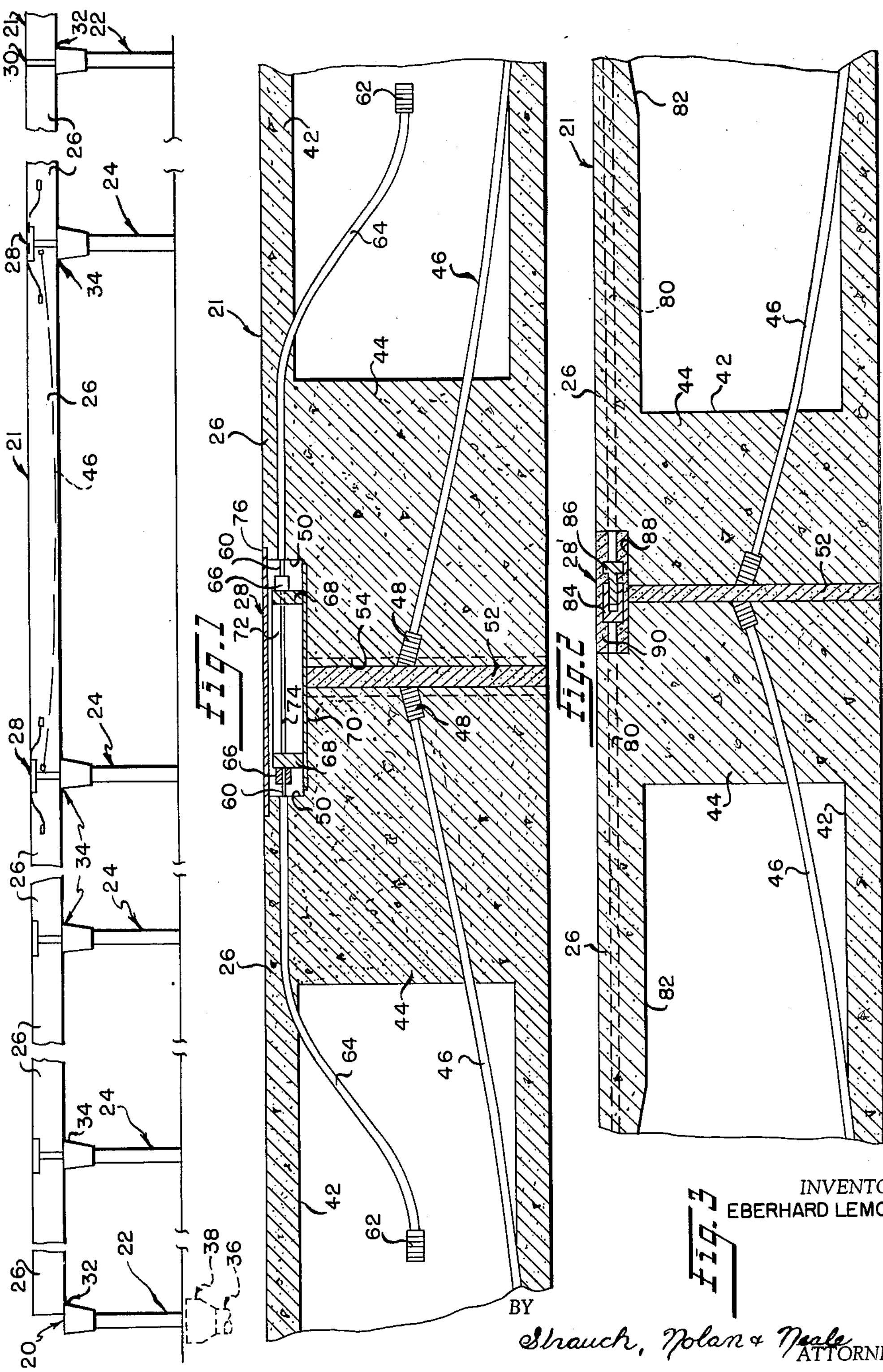
Dec. 28, 1965 E. LEMCKE 3,225,703

MONORAIL BEAMWAYS

Filed Sept. 18, 1963 5 Sheets-Sheet 1



INVENTOR
EBERHARD LEMCKE

BY
Strauch, Nolan & Neale
ATTORNEYS

Dec. 28, 1965 E. LEMCKE 3,225,703

MONORAIL BEAMWAYS

Filed Sept. 18, 1963 5 Sheets-Sheet 2

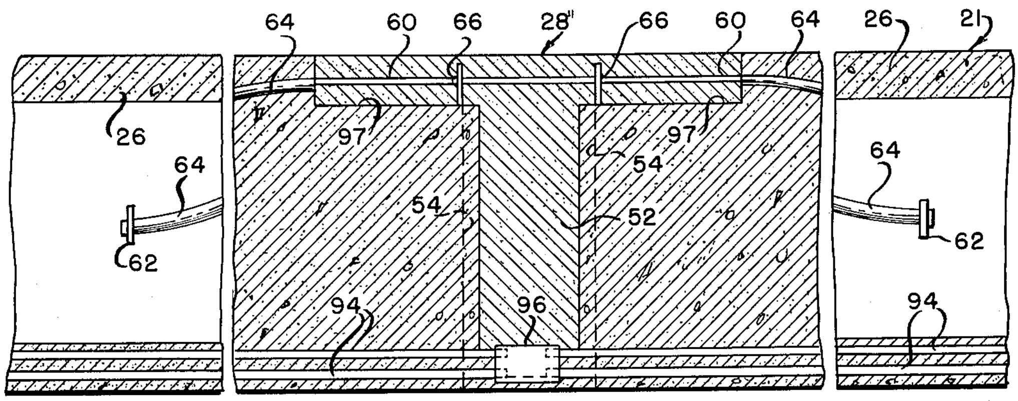


FIG. 4

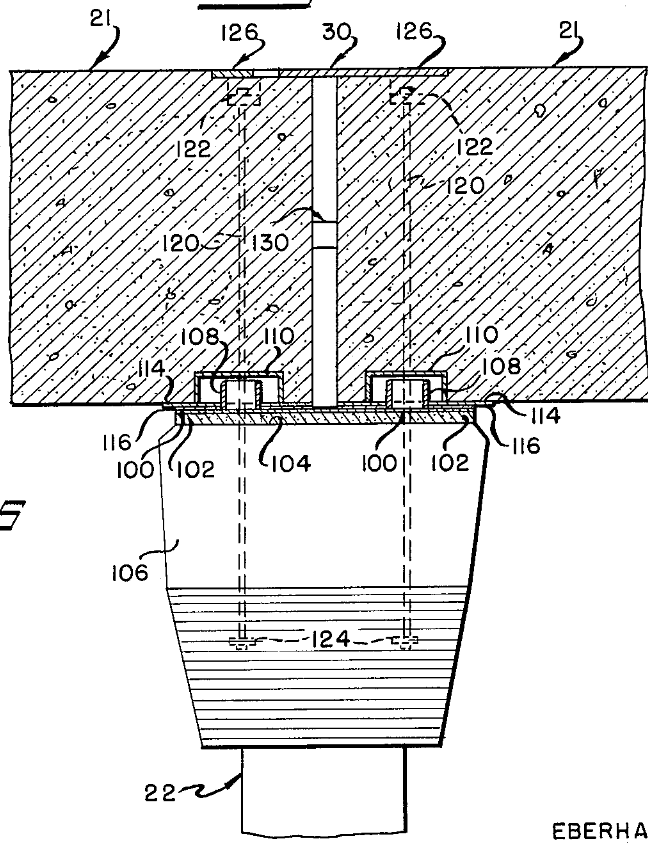


FIG. 5

INVENTOR

EBERHARD LEMCKE

BY Strauch, Nolan & Neale

ATTORNEYS

MONORAIL BEAMWAYS

Filed Sept. 18, 1963 5 Sheets-Sheet 3

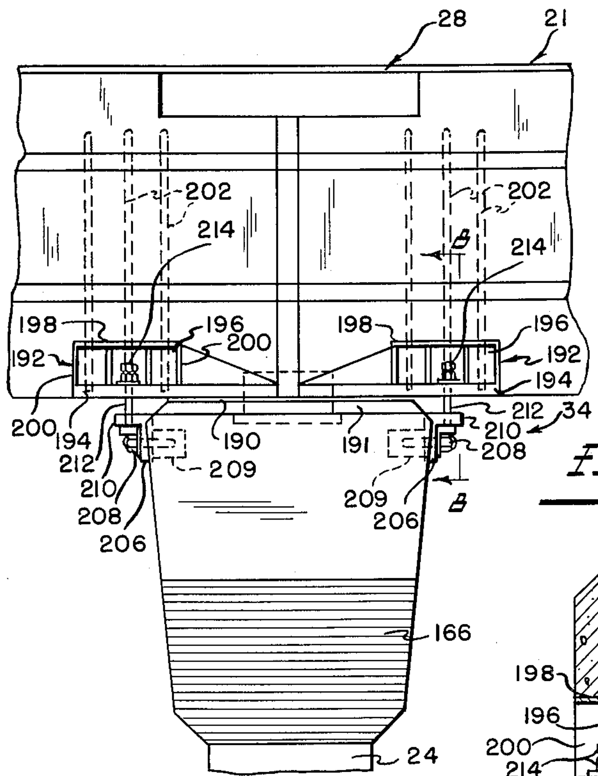


Fig-7

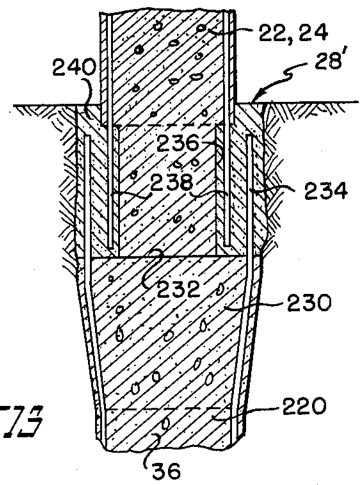


Fig-13

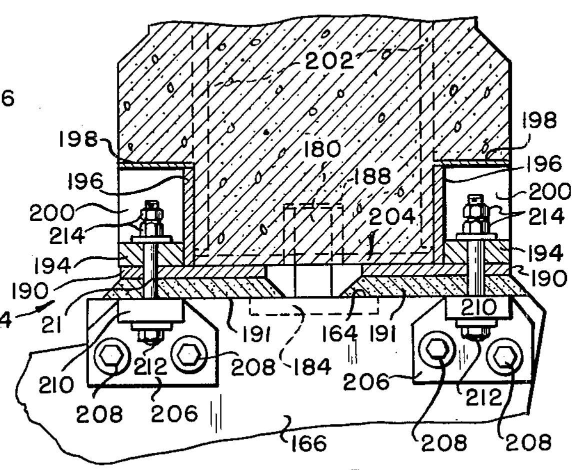
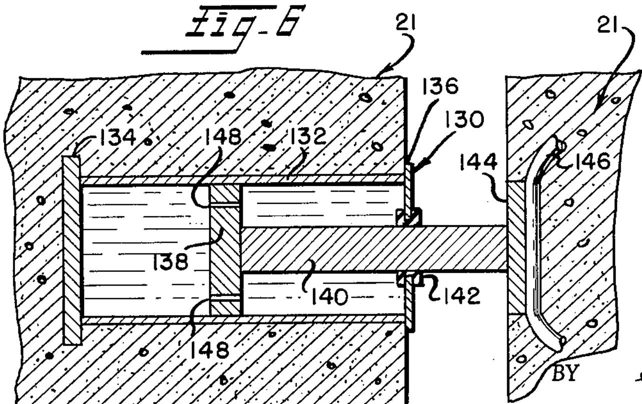


Fig-8

Fig-6



INVENTOR
EBERHARD LEMCKE

BY Strauch, Nolan & Neale
ATTORNEYS

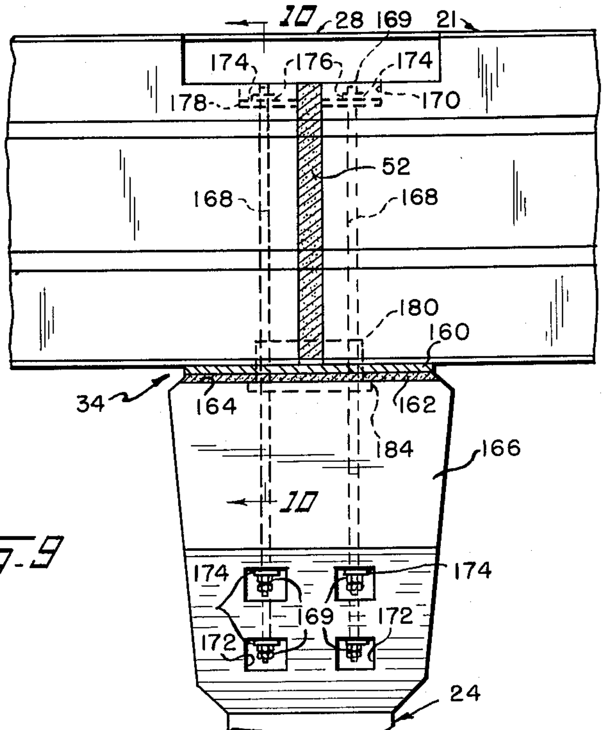


Fig-9

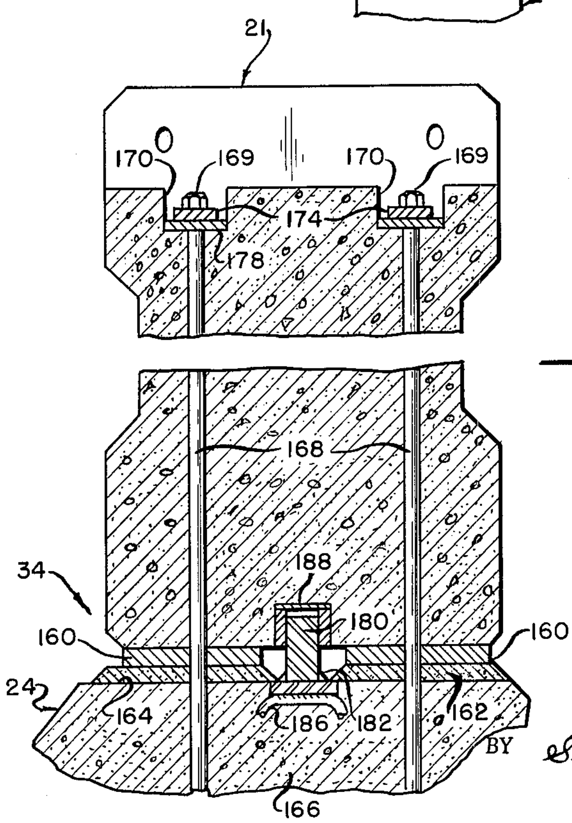


Fig-10

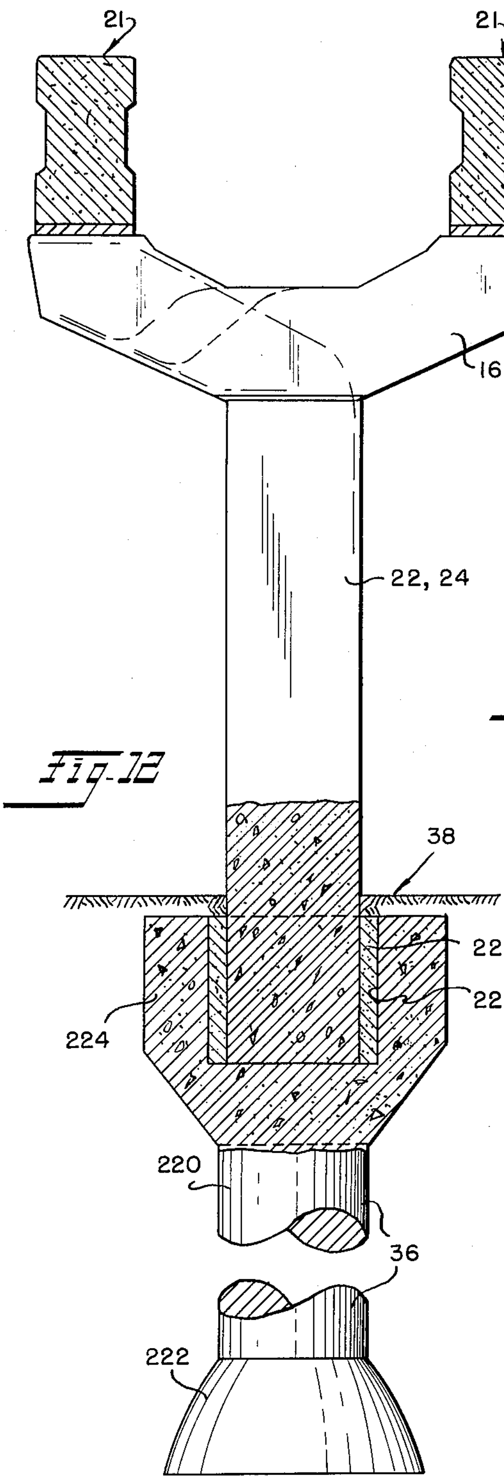
INVENTOR
EBERHARD LEMCKE

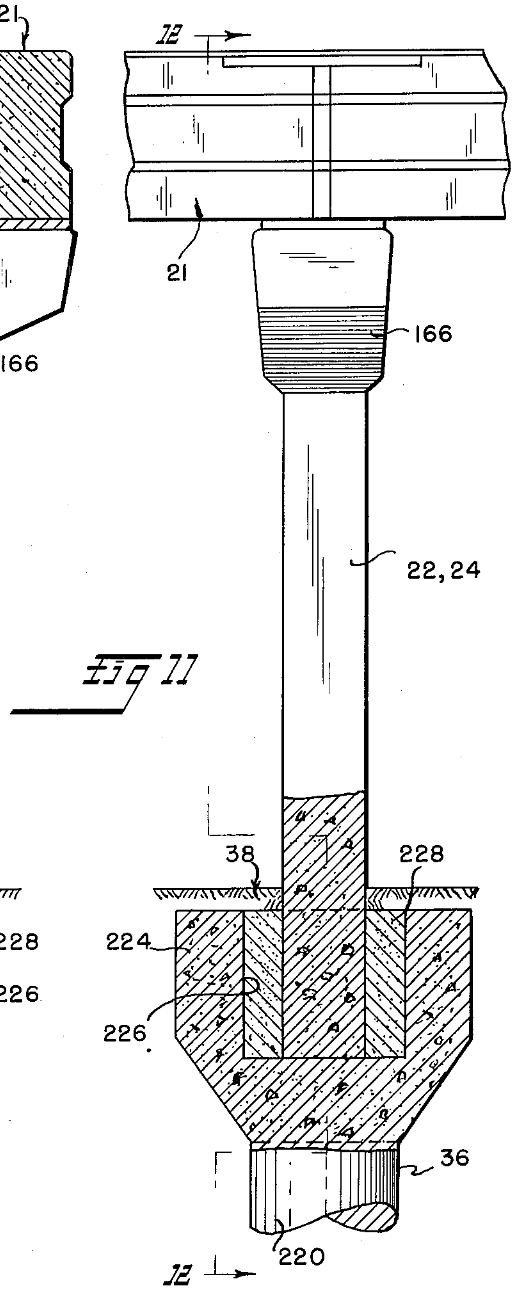
BY Strauch, Nolan & Neale
ATTORNEYS

Dec. 28, 1965 E. LEMCKE 3,225,703

MONORAIL BEAMWAYS

Filed Sept. 18, 1963 5 Sheets-Sheet 5





INVENTOR

EBERHARD LEMCKE

BY Strauch, Nolan & Neale

ATTORNEYS

United States Patent Office 3,225,703
Patented Dec. 28, 1965

3,225,703
MONORAIL BEAMWAYS

Eberhard Lemcke, Bellevue, Wash., assignor to Wegematic, New York, N.Y., a corporation of New York
Filed Sept. 18, 1963, Ser. No. 309,802
14 Claims. (Cl. 104—120)

This invention relates to beamways for monorail transportation systems and more particularly to improvements in the structure and methods of construction thereof.

The beamways of currently proposed urban, interurban, airport, and amusement park or fair ground sightseeing transportation systems and the like are of either the over-riding or the suspended car type. In both general types the train weight is supported upon elongated, horizontally extending beams. Some systems of the type to which the present invention relates, incorporate substantially rectangular, reinforced concrete beams supported above the ground on vertical, reinforced concrete columns. The monorail train rides on, and is primarily supported by, the top surfaces of the beams, and it is maintained upright and in a proper lateral position thereon by side wheels rolling along the lateral beam faces. Such beamways are conventionally composed of relatively short, single span, simply supported beams mounted at either end upon the vertical columns. One beam end is longitudinally fixed to one column and the opposite end is slidably mounted in an expansion joint upon an adjacent column to accommodate longitudinal movement with respect thereto as a result of concrete shrinkage or creep or thermal expansion. This type of monorail beamway construction is shown in co-pending application Serial No. 211,549 filed July 23, 1962, by Eberhard Lemcke for Railway Systems, Monobeam Type.

The improved beamway of the present invention is primarily characterized by continuous beams instead of the independent, simply supported beams heretofore employed. The continuous beams of the present beamway are much longer than the simply supported beams, and each continuous beam extends over and is supported by a plurality of vertical columns. These continuous beams may be straight, transitional, or curved (either simply or super-elevationally) as required.

The novel continuous beam construction of the present invention produces several distinct advantages in monorail transportation systems. First, a substantially smoother train ride results for the following reasons: (a) Mid-span bending moments due to the weight of the monorail train are inherently lower in the continuous beam arrangement, because of the bending moment transfer between the spans of the continuous beam, than they are in comparable simply supported beams, since in the latter arrangement no bending moments are applied to the beam at the simply supported beam ends. Therefore, a greatly reduced amount of pre-stress is required in a between-column section of the continuous beam and the resulting beam camber is reduced. This results in a flatter beamway and a smother train ride. (b) As the beam is continuous over a supporting column, there is no abrupt angular change in the plane of the top running surface at that point as there is between the cambered beams of the simply supported beamway. (c) And the elimination of expansion joints at every support column eliminates a source of irregularity or roughness in the beamway and therefore ensures a smoother train ride.

Second, reduced mid-span bending moments and resulting deflections permit a reduction in the amount of concrete and/or reinforcing steel in the beam or preferably permit an increase in the length of the beamway between columns. A reduction of the number of columns per beamway mile effects a significant economy in the cost

of the beamway and also produces a more aesthetically pleasing structure.

Third, the elimination of expansion joints at each supporting column considerably simplifies the bearing structure joining the beam and the columns.

As it is normally impractical to cast monorail beams in the field, and as transportation facilities limit the length of a continuous beam that can be transported to the monorail site, the continuous beams of the present invention are preferably made up of a plurality of precast beam sections which are spliced at the monorail site to form a continuous beam. These splices are advantageously positioned over the supporting columns intermediate the ends of the continuous beams. The splices incorporate novel means to post-tension the upper beam portions where they pass over the columns in order to enable these portions to withstand the tensile forces induced at the columns by the beam and train loads. The field splices are constructed to accommodate a range of spacings between the ends of adjacent beam sections. Consequently, an advantageous increase in the casting tolerances of the beam sections is made possible by this feature of the present invention.

The beamways of the present invention are further characterized by novel interconnections or bearings between the continuous beam and the support columns which prevent longitudinal movement between the beam and the columns. As a result of this structure, the braking or accelerating loads applied by the monorail train to the beam are distributed to the plurality of columns supporting the beam instead of being entirely imposed upon one column as is the case in the simply supported system. This reduced braking load permits a reduction in the cross-sectional dimensions of the support columns. This is not only economical and aesthetically pleasing, but the reduced column section also results in lower stresses in the columns when they are subjected to longitudinal bending forces under the influence of thermal expansion or contraction of the beam. The reduced braking load also permits simplification of the bearing structures between the beam and the columns since the reduced longitudinal loads can be absorbed frictionally at these bearings, thereby eliminating the need for a special longitudinal shear key.

Further, when longitudinally fixed interconnections or bearings between the continuous beam and the support columns in acordance with this invention are incorporated in a two-way-traffic dual beamway with side-by-side beams supported upon the vertical columns, the torsional stress induced in the vertical columns by reverse braking of two oppositely moving trains is materially reduced or eliminated. This occurs because the braking loads are transmitted to a plurality of columns and because the horizontally rigid framework of the beams and column crossarms achieved in such a dual beamway avoids transmission of the braking loads to the vertical columns as torques.

In one embodiment of the invention, beam bending moments are further reduced by employing beam-to-column bearings which prevent rotation between the continuous beams and columns about a transverse horizontal axis. Thus, bending moments can be applied to the continuous beams by the support columns to advantageously reduce mid-span beam moments.

The beamway of the present invention is also characterized by novel force transmission devices at the expansion joints between the ends of adjacent continuous beams. The expansion joints are incorporated in the beamway at predetermined intervals, for example, at every fifth column, to allow for concrete shrinkage and creep and for thermal expansion and contraction. The force transmission devices, which in one embodiment may be dashpot-type mechanisms, permit gradual longitudinal movement between the beam ends at the expansion joints but are effective to substantially rigidly transmit shock forces, such as train braking forces, between the beam ends. These novel devices therefore distribute the braking loads throughout a plurality of adjacent beams and the columns supporting them. Other devices having similar force transmission characteristics may be incorporated in the present invention. Suitable devices include, for example, chemical compositions having a low resistance to long term plastic deformation but high resistance to deformation under shock loads.

As described above, the vertical columns of the present beamway are subjected to longitudinal bending forces by train acceleration and braking, by beam expansion and contraction and, in one embodiment, by transfer of beam bending moments to the columns. Therefore, the present invention is also characterized by improved connections between the beam-supporting columns and their foundations. These connections incorporate socket-type formations at the upper ends of the foundations which support the lower ends of columns. A cementitious material or grout is placed in the sockets around the column ends to securely connect the columns to their foundations.

Accordingly, it is a primary object of the present invention to provide improved monorail beamways.

Further objects of the present invention include:

(1) The provision of improved monorail beamways capable of providing a smoother ride than has heretofore been possible;

(2) The provision of improved monorail beamways having continuous beams;

(3) The provision of improved, continuous, monorail beamways having decreased mid-span bending moments to reduce the strength requirements and increase the allowable span of the beam between support columns;

(4) The provision of improved monorail beamways having a reduced number of expansion joints to smooth the beamway and simplify the beam-to-column bearings;

(5) The provision of improved monorail beamways wherein braking and acceleration loads are distributed to a plurality of beam-supporting columns;

(6) In connection with the preceding object, the provision of beamways having simplified, frictional beam-to-column bearings;

(7) The provision of improved monorail beamways wherein adjacent continuous beams are inter-connected by novel force transmission devices;

(8) The provision of improved continuous-beam, monorail beamways fabricated from a plurality of rigidly spliced beam sections;

(9) The provision of improved, novel column-to-foundation connections for monorail beamways;

(10) The provision of improved monorail beamways wherein the component beam sections are installed in a manner permitting greater dimensional tolerances in their manufacture;

(11) The provision of improved methods of construcing monorail beamways to effect smoother train rides, more economical beamway construction, and more aesthetically pleasing beamway appearance;

(12) The provision of improved methods of splicing beam sections to form continuous-beam monorail transportation systems; and

(13) The provision of improved methods of interconnecting monorail beamway support columns and their foundations.

These and other objects and novel features of the present invention wil more fully appear from the following description and appended claims when read in connection with the accompanying drawings wherein:

FIGURE 1 is a broken side view of a continuous beam portion of a beamway constructed according to the present invention;

FIGURE 2 is a longitudinal vertical section through a splice between beam sections of the continuous beam of FIGURE 1;

FIGURE 3 is a longitudinal vertical section through a splice between beam sections according to a modified embodiment of the present invention;

FIGURE 4 is a longitudinal vertical section through a splice between beam sections according to a further modified embodiment of the present invention;

FIGURE 5 is a longitudinal vertical section through an expansion joint provided at the end of each continuous beam of FIGURE 1 and also shows the expansion joint's beam-to-column bearing structure;

FIGURE 6 is a longitudinal vertical section through a brake load transfer mechanism at the expansion joint of FIGURE 5;

FIGURE 7 is a side view of a spliced continuous beam according to the present invention and particularly shows a fully fixed bearing structure rigidly securing the continuous beam to a support column;

FIGURE 8 is a transverse vertical section of the bearing structure taken substantially along line **8—8** of FIGURE 7;

FIGURE 9 is a longitudinal vertical section through a spliced beam of the present invention and shows a modified bearing structure employed between the beam and its supporting column to permit flexibility therebetween;

FIGURE 10 is a transverse vertical section of the modified bearing structure taken substantially along line **10—10** of FIGURE 9;

FIGURE 11 is a partially sectioned side view of a portion of the beamway of FIGURE 1 showing the novel column-to-foundation connection of the present invention;

FIGURE 12 is a partially sectioned view of the column-to-foundation connections taken substantially on line **12—12** of FIGURE 11; and

FIGURE 13 is a transverse vertical section through a modified embodiment of a socket-like connection between a beam-supporting column and a beamway foundation.

As shown generally in FIGURE 1, the novel beamway **20** of the present invention includes a plurality of continuous beams **21** of determinate length, each supported on two exterior columns **22** and, in this specific embodiment, four interior columns **24**. Beams **21** are formed from a number of beam sections **26** which are so arranged with respect to columns **22** and **24** that the juxtaposed ends of adjacent sections **26** of the continuous beam are supported on the interior support columns **24** and are there rigidly interconnected by splices **28** to form the continuous elongated beam **21** extending between exterior columns **22**.

Opposite ends of adjacent continuous beams **21** meet at, and are simply supported upon, the exterior columns **22**. Expansion joints **30** are provided at exterior columns **22** between juxtaposed beam ends to allow for concrete shrinkage and creep and thermal expansion and contraction in the continuous beams. Sliding bearings **32** are provided between the ends of beams **21** and exterior support columns **22** to permit longitudinal sliding motion therebetween. Non-sliding bearings **34** are employed between each interior column **24** and the portion of the continuous beam passing thereover to prevent longitudinal motion of the beam across the top of these columns. Foundations **36** support each interior and exterior column and include socket connections **38** rigidly interconnecting the columns with their foundations.

Beam splices 28

As shown in greater detail in the embodiments of FIGURES 2, 3, and 4, the beam sections **26** are rigidly interconnected by splices **28** to form the continuous beam **21**. As shown in FIGURE 2, beam sections **26** have hollow central cores **42**, substantially solid end portions **44**, and conventional draped tendons **46** with anchors **48** at their opposite ends to pre-stress the beams and provide the camber necessary to accommodate the live load of the monorail train. After beam sections **26** have been properly positioned in aligned orientation on their support columns, the spaces between the beam sections are filled with a cementitious material or grout **52** to the level of the post-tensioning recesses **50** in the upper portions of the interior ends of the beam sections, that is, the ends intermediate the length of the continuous beam **21**. Vertical recesses **54** in the interior ends of beam sections **26** when filled with grout provide a keyed interlock between each pair of beam ends and the cementitious mass of grout **52** therebetween and prevent lateral slippage or twisting between beam sections.

Post-tensioning cables **60** at the interior ends of the beam sections accommodate the tensile forces applied to the upper portions of the beam where it passes over the interior support columns. These cables have anchors **62** at points substantially removed from the ends of the beam sections. Cables **60** extend from anchors **62** through cable tubes **64** to the post-tensioning recesses **50** in the beam section ends.

Post-tensioning anchors **66** at the recess ends of cables **60** are connected to post-tensioning blocks **68** enabling a jack to be used to tension the cables **60**. Blocks **68** slide upon a plate **70** in the bottom of the recess during the post-tensioning procedure. Blocks **68** and anchors **66** are then securely welded together by spacer plates **72** and rods **74** to maintain the post-tensioning cables **60** in a stressed condition.

Each post-tensioning recess **50** is covered by a plate **76** to form a smooth top-running surface for the monorail beam. Similar cover plates (not shown) are preferably provided to smooth the side-running surfaces of beam **21**.

FIGURE 3 shows a modified splice embodiment **28'** between beam sections **26** of the continuous beam **21**. In this embodiment, reinforcing rods **80**, cast integrally in the beam section end portions **44**, extend toward the interiors of the beam sections above central cores **42**. The upper portion of the beam sections are enlarged as at **82** to accommodate the necessary reinforcing steel work. Reinforcing rods **80** terminate in interfitting anchor blocks **84** and **86** in post-tensioning recess **88**. As in the splice shown in FIGURE 2, the spaces between the beam section ends are filled with grout **52**. After hardening of the grout, the beams are post-tensioned by forcibly jacking anchor blocks **84** and **86** into engagement and welding them together to retain rods **80** in a stressed tensile condition. The post-tensioning recess **88** may then be filled with grout **90** to smooth the running surfaces of the beam or cover plates similar to those described above for the embodiment of FIGURE 2 may be used for this purpose.

A third splice embodiment **28"** is shown in FIGURE 4. In this embodiment, the lower reinforcing steel rods **94** of each beam section **26** are welded to interconnecting members such an angles **96** before filling the spaces between the beam section ends with grout **52** in order to transfer compressive stresses between opposite beam section ends at the bottom of the splice and to insure continuity of the beam sections. After welding reinforcing rods **94**, the splice is grouted to the level of post-tensioning recessees **97**, and after the grout cures the beam sections are post-tensioned at the upper portions of the splice in substantially the same manner as in the splice embodiment of FIGURE 2. As shown in FIGURE 4, post-tensioning recesses **97** may be filled with grout to smooth the beam running surfaces.

Expansion joints 30 and exterior bearings 32

As shown in detail in FIGURE 5, the ends of adjacent continuous beams **21** are supported upon an exterior column **22** in an expansion joint **30**. Joint **30** includes a steel bearing plate **100** separated by a bed of grout **102** from the upper bearing surface **104** of the crossarm **106** of exterior column **22**. Vertical, transverse shear lugs **108**, which are preferably cylindrical, are rigidly welded

on plate **100** and are slidably received in shear lug housing **110** fabricated from steel plates and cast in the beam ends at the expansion joint. Shear lugs **108** resist transverse movement between the ends of beams **21** and exterior columns **22**.

The lower end surfaces of beams **21** are provided with flexible fabric pads **114** faced with plates **116**, which, in the preferred embodiment are stainless steel. Plates **116** slidably engage the bearing plates **100** on the column crossarms **106**.

Elongated tie-down bolts **120** extend from anchorage points **122** near the upper portion of beams **21** to anchorage points **124** well below the top bearing surface of crossarm **106**. Tie-down bolts **120** are tensioned just sufficiently to prevent lateral tipping of beams **21** but to permit longitudinal movement between the ends of the beams and the column crossarm **106**. Conventional fingerplates **126** at the ends of beams **21** interlock to form smooth running surfaces across the expansion joint.

To transfer braking loads (which may be applied to one continuous beam **21** by a monorail train thereon) to adjacent beams and thereby distribute the braking loads to a greater number of interior columns, a transfer mechanism **130** is provided between the juxtaposed beam ends of adjacent beams. As best shown in FIGURE 6, transfer mechanism **130** is a dashpot-like device comprising a cylinder **132** closed by end plates **134** and **136** and is cast in the end of one beam **21**. A piston **138** in cylinder **132** is connected to a piston rod **140** which extends outwardly through cylinder end wall **136** through a seal **142**. Piston rod **140** is fixed to a plate **144** cast securely in the end of the adjacent beam and retained by reinforcing rods **146**. Piston **138** is provided with a plurality of small orifices **148** connecting the two chambers of cylinder **132** on opposite sides of the piston.

This mechanism permits slow, gradual, longitudinal relative movement between the ends of adjacent beams **21** caused by concrete shrinkage or creep or thermal expansion or contraction of the beams. However, rapid movement between the beams as might be occasioned by monorail train acceleration or braking is effectively prevented by a transfer of such short duration forces from the beam on which the monorail train is located through the dashpot mechanism to the adjacent continuous beams **21** and from them to further adjacent beams and so on. In this manner, braking loads are distributed to a large number of interior columns through non-sliding interior bearings **34**.

Interior bearings 34

As shown in FIGURES 9 and 10, spliced beam **21** is secured to interior columns **24** by bearings **34** consisting of fabric pads **160** installed between the beam and a layer of grout **162** on the upper bearing surface **164** of column crossarm **166**. Fabric pads **160** are sufficiently flexible to allow beam **21** to rotate about a transverse horizontal axis with respect to the crossarm **166**. Relatively widely laterally spaced tie-down bolts **168** on either side of splice **28** prevent lateral tilting of the beam **21** with respect to the column. These bolts are tensioned, as by end nuts **169**, to create sufficient friction between the lower surfaces of the concrete beam, the upper surface of the grout layer **162**, and the fabric pad **160** to prevent beam **21** from sliding longitudinally on the column.

To permit rotation between the beam and the column, tie-down bolts **168** are arranged with minimal longitudinal spacing and are made relatively long to minimize change of tension during such rotation. The bolts extend from tie-down bolt recesses **170** located near the upper portions of beams **21** to crossarm recesses **172** located at positions well below the bearing surface **164** of the crossarm. To further enhance the flexibility of bearings **34**, tie-down bolts **168** are secured between fabric pads **174** at either end of the bolts. Anchor plates **178** are disposed under the fabric pads **174** in tie-down recesses **170**.

To prevent transverse movement between beams **21** and crossarms **166**, a shear key **180** is securely welded at **182** to a mounting plate **184** which is rigidly welded to reinforcing bars **186** within the crossarm. Shear key **180** extends upwardly into shear key housings **188** which are fabricated from steel plates and cast within the lower surface of beam **21** at the interior beam section ends.

FIGURES 7 and 8 show a modified interior bearing **34'**. Bearings **34'** prevent rotation between beams **21** and interior columns **24** about horizontal transverse axes and are therefore capable of transferring bending moments between the beams and the columns. Bearings **34'** include steel bearing plates **190** mounted upon a layer of grout **191** located on the upper bearing surface **164** of column crossarm **166**. Fabricated, plate steel, beam fixtures **192** are secured within continuous beam **21** on both sides of splices **28**.

Fixtures **192** include bottom plates **194**, vertical back plates **196**, top plates **198**, and rigidifying transverse plates **200**. Vertically extending reinforcing rods **202** extend upwardly into the interior of the beam section ends from rigid welded connections with back plates **196**. Beam bearing plates **204** extend transversely across the ends of the beam sections between fixtures **192** and bear against plates **190** of the column crossarm.

Crossarm mounting fixtures **206** are rigidly mounted on opposite sides of the column crossarm by bolts **208** extending into bolt receiving portions **209** of the crossarm. Short vertically extending beam mounting bolts **212** extend through lugs **210** on column fixtures **206** and through the lower plates **194** of the bearing fixtures **192** of the beam. Bolts **212** are secured by locking nuts **214**.

Because beam mounting bolts **212** are wide spread and relatively short, and because of the steel-to-steel bearing plate contact, bearings **34'** are rigid and effectively prevent transverse rotation between continuous beam **21** and interior columns **24**. Thus bearings **34'** transfer beam bending moments to the interior columns to further reduce stress and deflection of the continuous beams.

Column to foundation connections 38

As shown in FIGURES 11 and 12, the foundations **36** for columns **22** and **24** each include a vertically elongated cylindrical section **220** terminating at its lower end in a semi-cylindrical pedestal **222** and, at its upper end, in a socket member **224**. In the preferred embodiment, socket member **224** is generally square and has a substantially cylindrical internal socket opening **226**. Columns **22** and **24** rest in the bottom of socket openings **226** and, after being properly oriented and aligned, are secured in place by filling socket **224** with grout **228**. After the grout cures, the surrounding ground is releveled over the top of the socket to achieve an aesthetically pleasing beamway appearance.

A modified column-to-foundation connection **38'** is shown in FIGURE 13. In this embodiment the generally cylindrical elongated portion **220** of foundation **36** terminates, at its upper end, in a flared portion **230** having an upper column bearing surface **232**. Reinforcing rods **234** protrude upwardly from surface **232** of the foundation around the periphery of flared portion **230**. Columns **22** and **24** are modified in this embodiment by cutting away peripheral portions **236** at their lower ends to expose those column reinforcing bars **238** adjacent reinforcing bars **234** of the foundation when the column is in position. The surrounding ground forms a socket at the upper end of the foundation into which grout **240** is poured around the lower end of columns **22** and **24**. The grout rigidly interlocks reinforcing bars **234** and **238**, forming a rigid, secure, and very efficient column-to-foundation connection.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

1. In a monorail transportation system:
(a) a series of adjacent, aligned, elongated continuous beams forming a vehicle supporting and guiding beamway;
(b) a plurality of longitudinally spaced beam-supporting columns intermediate the ends of each beam, said beam being longitudinally fixed with respect to said columns; and
(c) expansible means between the juxtaposed ends of adjacent beams to accommodate longitudinal movement therebetween including force transmitting means comprising a fluid filled cylinder mounted at the end of one beam and a cooperating piston mounted in said cylinder and secured to the juxtaposed end of an adjacent beam to provide a dashpot effect for longitudinal movement therebetween.

2. A combination as defined in claim **1** together with means fixing said beams to said columns so as to transfer bending moments therebetween.

3. A combination as defined in claim **2** wherein said means fixing said beams to said columns include:
(a) vertically aligned fixtures rigidly mounted on said beams adjacent bottom support surfaces thereof and on said columns adjacent the upper beam-supporting surfaces thereof, said fixtures being located at positions substantially removed from vertical transverse center planes through said columns; and
(b) relatively inflexible mounting means connecting the fixtures on said beams and to those on said columns to rigidly clamp said beams on said columns and thereby transfer beam bending moments to said columns.

4. A combination as defined in claim **1** together with means connecting said beams to said columns and enabling beam rotation upon the columns about a horizontal axis which is normal to a plane through the longitudinal axis of the beam.

5. A combination as defined in claim **4** wherein said connecting means include:
(a) compressible members positioned between a bottom support surface of said beams and the top beam-supporting surfaces of said columns; and
(b) vertically elongated means extending from an upper portion of said beams to a portion of said columns substantially below the beam-supporting surface thereof to flexibly clamp said beams on said columns and thereby frictionally prevent longitudinal sliding movement therebetween.

6. A combination as defined in claim **1** together with vertically elongated column-supporting foundations having socket means at the upper ends thereof to accommodate the lower ends of said columns and a cementitious mass in said socket means to securely connect said columns to said foundations.

7. A combination as defined in claim **6** wherein said columns and said foundations have elongated reinforcing means protruding from the lower and upper ends thereof, respectively, into said cementitious mass to rigidify the connection between said columns and said foundations.

8. A combination as defined in claim **1**, wherein there are, between each of the vertical columns supporting the juxtaposed ends of adjacent beams and the two beam ends supported thereon, means including sliding bearings accommodating relative longitudinal movements between said beam ends and said columns.

9. In a monorail transportation system:
(a) a series of adjacent, aligned, elongated continuous beams forming a vehicle supporting and guiding beamway; each of said beams being comprised of a plurality of aligned, elongated, spaced concrete beam sections;

(b) a plurality of longitudinally spaced beam-supporting columns intermediate the ends of each beam, said beam sections being longitudinally fixed with respect to said columns;

(c) first beam section connecting means between the spaced, juxtaposed ends of adjacent beam sections to rigidly transmit compressive forces therebetween;

(d) second beam section connecting means separate from said first connecting means between said beam ends to rigidly transmit tensile forces therebetween and thereby effect with said first means a rigid interconnection between said beam sections; and

(e) expansible means between the juxtaposed ends of adjacent beams to accommodate longitudinal movement therebetween including force transmitting means comprising a fluid filled cylinder mounted at the end of one beam and a cooperating piston mounted in said cylinder and secured to the juxtaposed end of an adjacent beam to provide a dashpot effect for longitudinal movement therebetween.

10. A monorail transportation system as defined in claim **9** wherein said interconnecting means includes a mass of cementitious material between said juxtaposed beam ends.

11. A beamway as defined in claim **10** wherein said juxtaposed beam section ends have vertically extending deformations to interfit with said cementitious material to interlock said sections.

12. A monorail transportation system as defined in claim **9** wherein said second connecting means comprise:

(a) cables anchored to said beam sections at points substantially removed from the ends thereof;

(b) cable tubes enclosing and leading said cables to the upper portions of the beam ends; and

(c) means to pre-stress and fixedly join said cables at the juxtaposed ends of adjacent beam sections.

13. A monorail transportation system as defined in claim **9** wherein said second connecting means comprise:

(a) elongated reinforcing members cast in said beam sections to protrude from said juxtaposed beam section ends; and

(b) means to post-stress and join the protruding members of said adjacent beam sections.

14. In a monorail transportation system, a beamway comprising:

(a) a series of adjacent, aligned, elongated, continuous beams for supporting and guiding a vehicle on said beamway, each said continuous beam including:

(1) a plurality of elongated beam sections in aligned relation with the opposite ends of adjacent beam sections being in juxtaposed relation, and

(2) splicing means between adjacent sections to rigidly interconnect them into a continuous beam, said splicing means including connecting means of cementitious material positioned between said juxtaposed ends to secure said ends in fixed spaced relation and to transmit compressive forces therebetween, said juxtaposed beam section ends having vertically extending deformations to interfit with said cementitious material to interlock said sections, and connecting means between the upper portions of said juxtaposed ends to transmit tensile forces therebetween;

(b) a plurality of exterior columns each positioned to support the juxtaposed ends of adjacent continuous beams;

(c) exterior bearing means positioned between said exterior columns and the ends of said continuous beams to permit longitudinal sliding movement therebetween;

(d) a plurality of interior columns positioned to support said continuous beams at the locations of said splicing means between said beam sections;

(e) interior bearing means located between said interior columns and the adjacent portions of said continuous beams adapted to prevent longitudinal motion therebetween;

(f) force transmitting means between the juxtaposed ends of adjacent beams at said exterior columns, comprising a fluid filled cylinder mounted at the end of one beam and a cooperating piston mounted in said cylinder and secured to the juxtaposed end of an adjacent beam to provide a dashpot effect for longitudinal movement therebetween;

(g) a plurality of vertically elongated column-supporting foundations beneath each of said exterior and interior columns; and

(h) means connecting said foundations to said columns including socket means at the upper ends of said foundations adapted to receive the lower ends of said columns and means forming a cementitious mass in said socket means around said lower column ends to fixedly connect said columns to said foundations.

References Cited by the Examiner

UNITED STATES PATENTS

1,667,970	5/1928	Hermann	50—25 X
2,014,430	9/1935	Fish	104—125
2,630,075	3/1953	Olmsted	104—125
2,985,376	5/1961	Smith	238—122
3,090,326	5/1963	Goodell et al.	104—124

FOREIGN PATENTS

624,406	7/1961	Canada.
758,226	10/1956	Great Britain.

ARTHUR L. LA POINT, *Primary Examiner.*

LEO QUACKENBUSH, *Examiner.*