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Whitbread et al.

[11] **3,709,116**

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[54] SLIP-FORM PAVING MACHINES

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[30] **Foreign Application Priority Data**

Mar. 2, 1970 Great Britain 9814/70

[52] **U.S. Cl.** ..... **94/46 AC**

[51] **Int. Cl.** **E01c 19/48**

[58] **Field of Search** 94/46, 45, 44

[56] **References Cited**

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Primary Examiner—Nile C. Byers, Jr.

Attorney—Sommers & Young

[57] **ABSTRACT**

A surface forming machine has a conforming member for conforming a surface of a roadway which is adjustable laterally of the machine. A sensing device is mounted for lateral movement with the conforming member for sensing a datum controlling the lateral position of the conforming member. Actuating means cause lateral adjustment of the conforming member to maintain the sensing device centered with respect to the datum. Programmed control means driven in synchronism with the movement of the machine along the roadway cause movement of the sensing device laterally relatively to the conforming member, whereby the consequent lateral adjustment of the conforming member by the actuating means to restore the sensing device to its centered position with respect to the datum varies the relationship between the lateral position of the conforming member and the datum. Similar sensing devices and programmed control means can be provided for controlling the vertical height and transverse and longitudinal attitudes of the conforming member.

17 Claims, 8 Drawing Figures

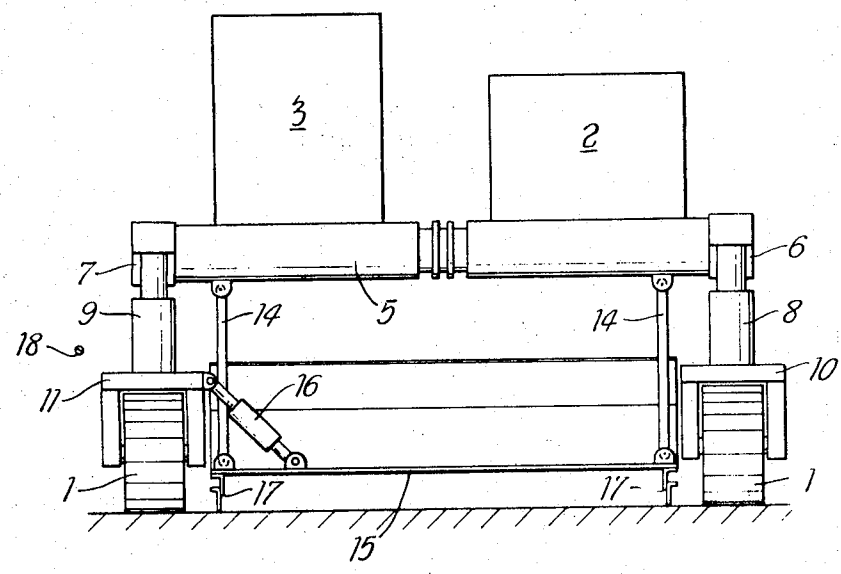


FIG.1

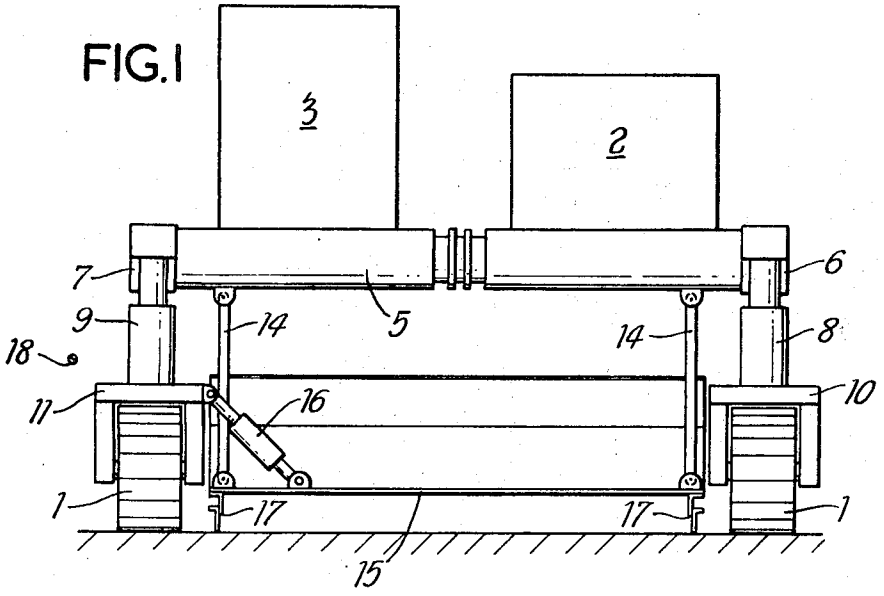
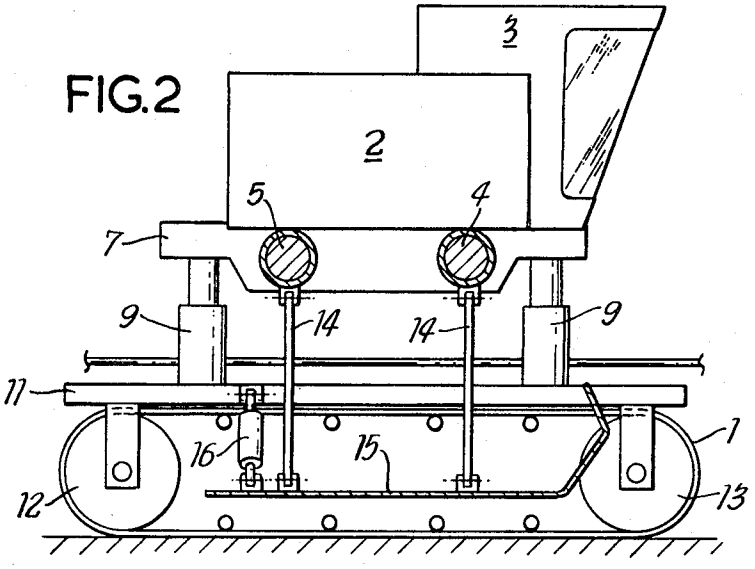


FIG.2



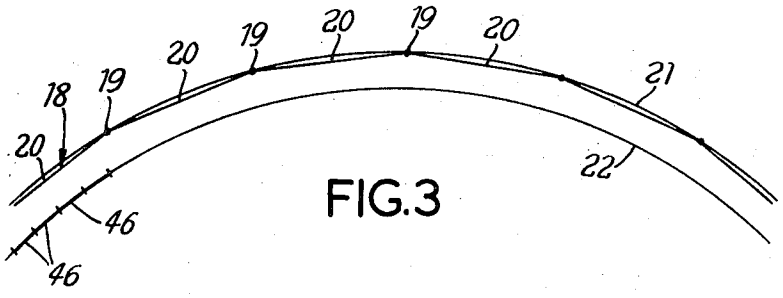

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FIG. 3

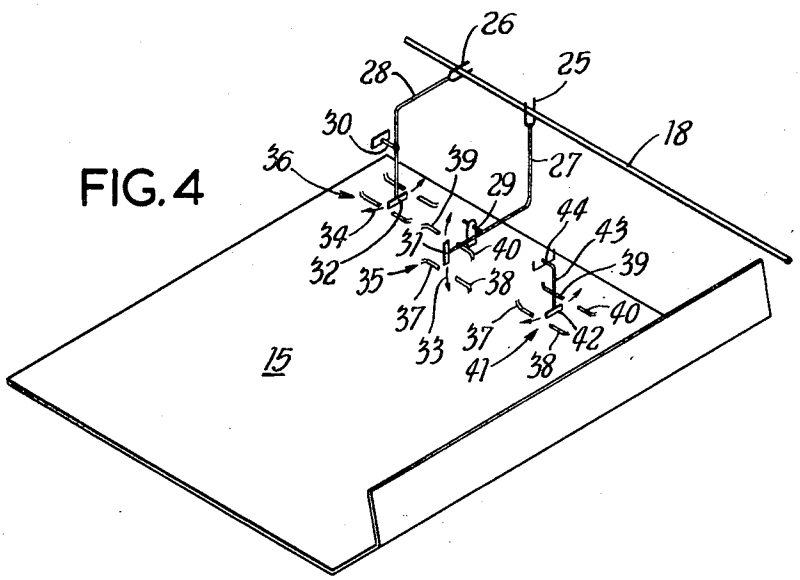
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FIG. 4

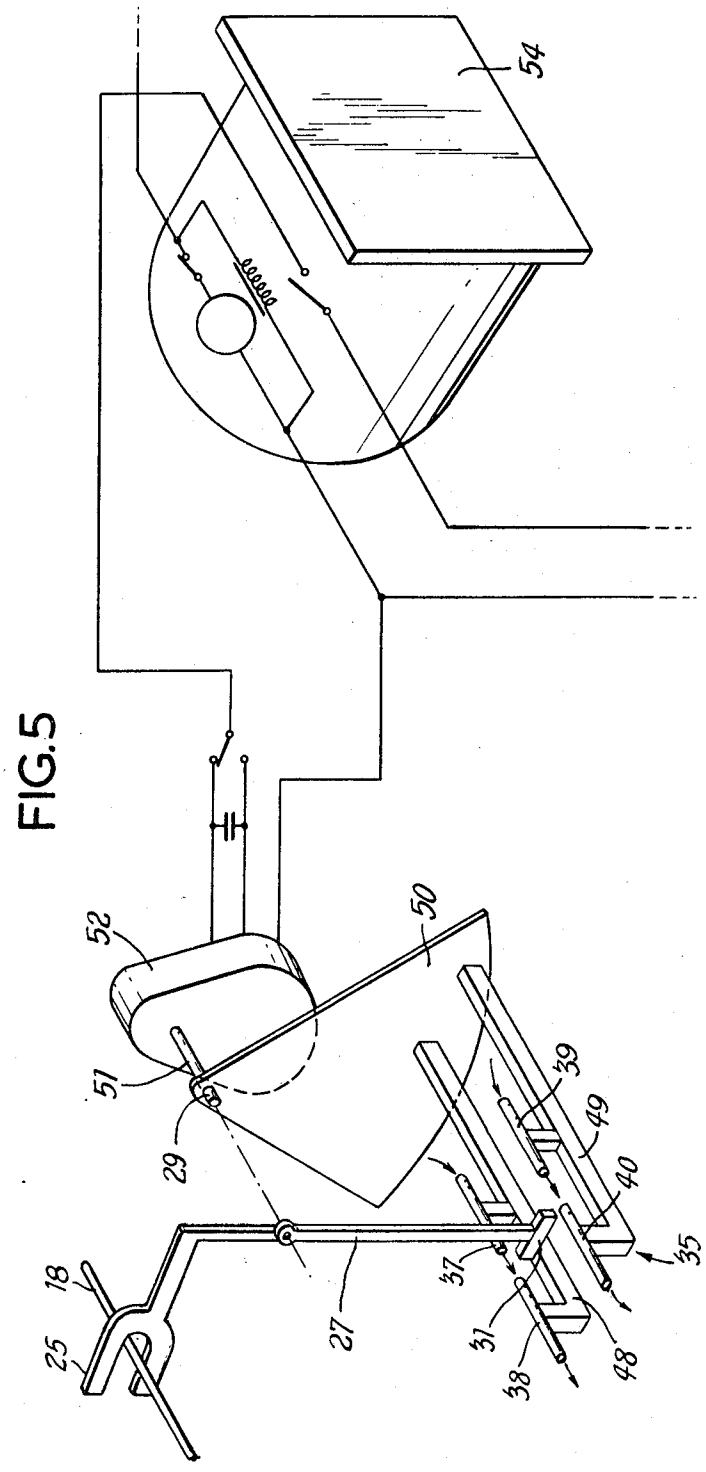

FIG.5

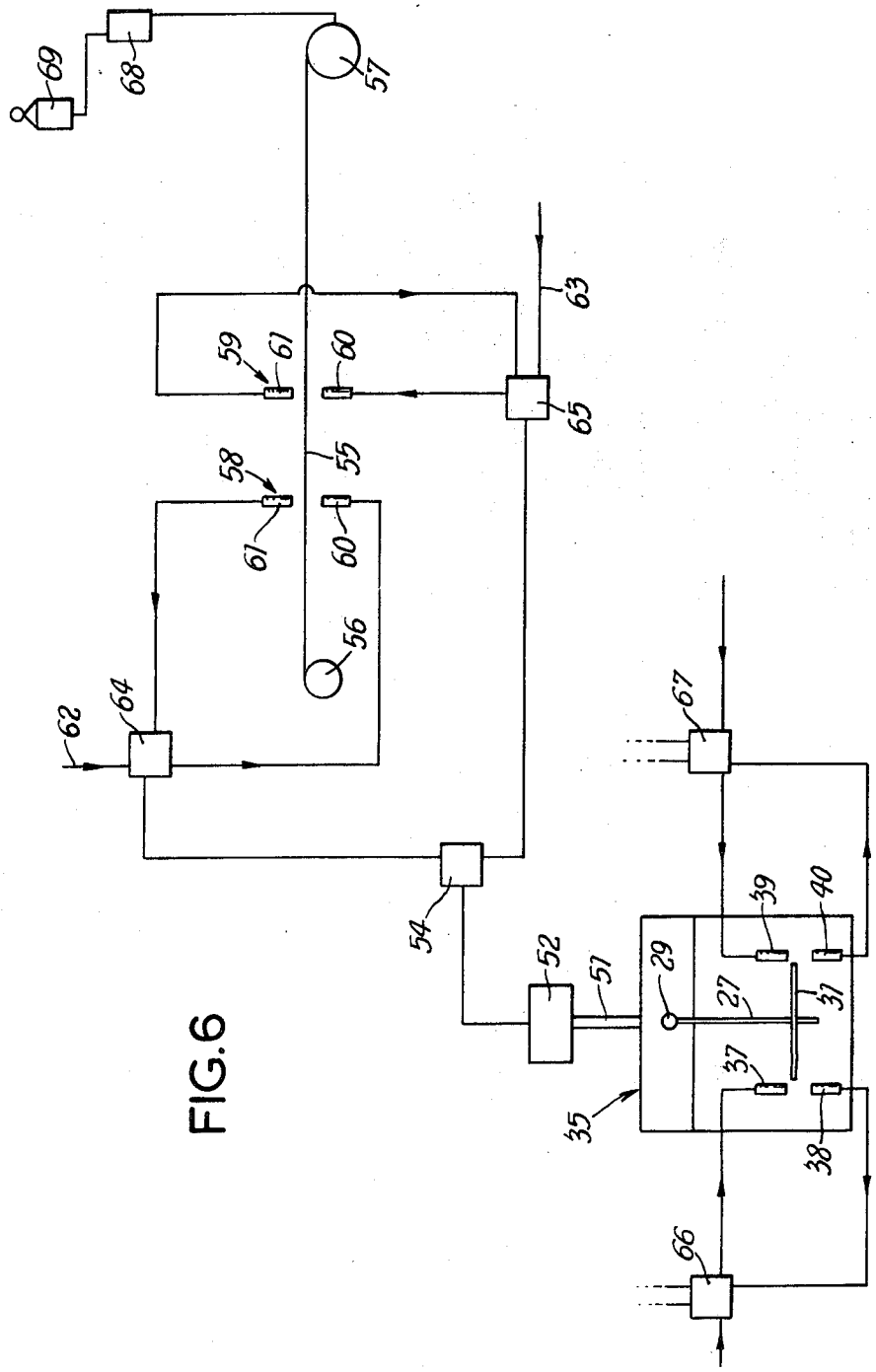
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FIG.6

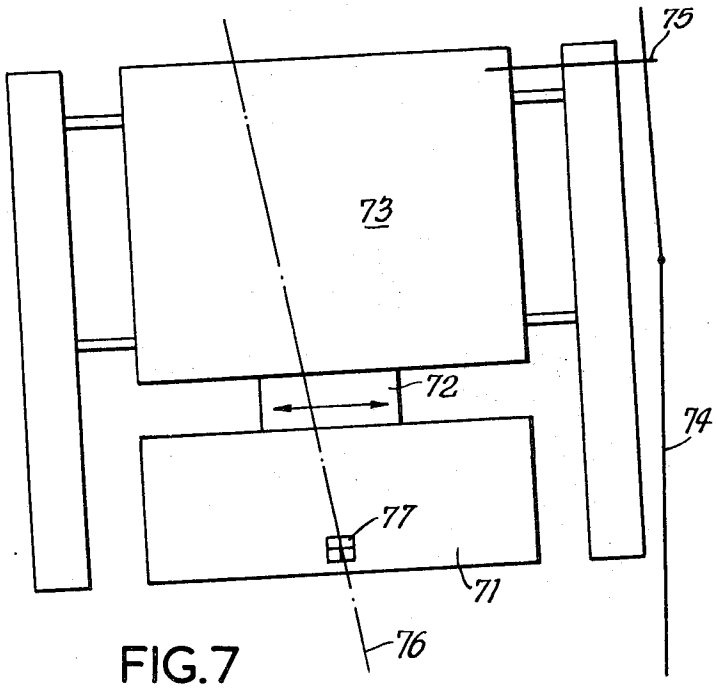

FIG.7

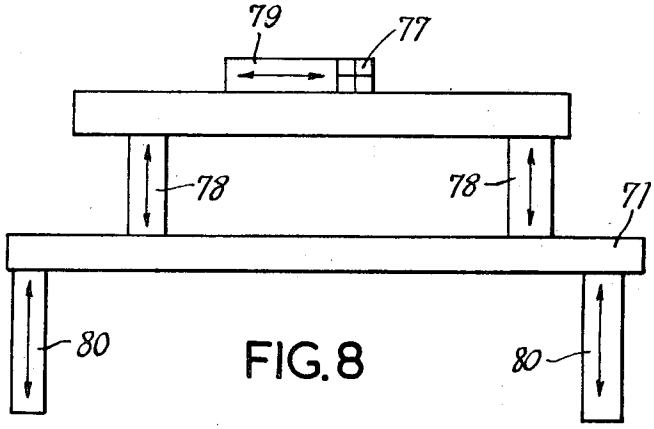

FIG.8

SLIP-FORM PAVING MACHINES

This invention relates to surface forming machines, and more particularly, but not exclusively, to slip-form paving machines for laying cement-concrete. Other applications of the invention are in graders and other earth moving equipment in which it is required to provide an accurately level or contoured surface along a predetermined route.

Slip-form paving machines are used in constructing motor roads and more recently in constructing rail roads by laying concrete slab foundations for supporting the rails of railway track. Machines of this kind are provided with a conforming plate which conforms the top surface of the cement-concrete layer to a desired level and profile. In the past, it has been necessary to survey the intended route for a road including the positioning of guide wires with extreme accuracy for subsequent guiding of the paving machine and control of the conforming plate. This preparatory surveying operation has proved both time-consuming and disproportionately expensive.

The object of the invention is to provide a surface forming machine such as a slip-form paving machine which has a control system such that the preparatory surveying operation can be less onerous.

According to this invention there is provided a surface forming machine comprising, a conforming member for conforming a surface of a roadway as the machine moves along the roadway and which is adjustable laterally of the machine, sensing means mounted for lateral movement with the conforming member for sensing a datum controlling the lateral position of the conforming member as the machine moves along the roadway, actuating means for causing lateral adjustment of the conforming member to maintain the sensing means centered with respect to the datum, and programmed control means arranged to be driven in synchronism with the movement of the machine along the roadway for moving the sensing means laterally relatively to the conforming member, whereby the consequent lateral adjustment of the conforming member by the actuating means to restore the sensing means to its centered position with respect to the datum varies the relationship between the lateral position of the conforming member and the datum.

Thus controlled adjustment of the sensing means relatively to the conforming member in accordance with a predetermined programme can, with a rectilinear datum line cause the conforming member to follow a curve for example as the machine moves forward. Through suitable level control means the attitude of the conforming member can be controlled to impart a desired cant or gradient forming slope to the conforming member.

The sensing means may comprise a photocell arrangement and the datum line can then conveniently be provided by a laser-beam.

Two constructions of slip-form paving machine in accordance with the invention will now be described by way of example with reference to the accompanying diagrammatic drawings, in which:

FIG. 1 shows a rear elevation of the first machine construction,

FIG. 2 shows a sectional side elevation of the machine,

FIG. 3 is a diagram illustrating the operation of the machine,

FIG. 4 is a perspective view of the conforming plate of the machine illustrating the datum sensing units mounted thereon,

FIG. 5 illustrates the adjustability of a representative one of the datum sensing unit relatively to the conforming plate, and

FIG. 6 illustrates the programmed control system for adjusting the datum sensing units relatively to the conforming plate.

FIG. 7 is a view illustrating the lateral positioning system for the conforming plate of the second machine construction, and

FIG. 8 is a view illustrating the vertical positional control of the conforming plate and the horizontal and vertical adjustment of the sensing means relatively to the conforming plate of the second machine construction.

Referring to FIGS. 1 to 6 the slip-form paving machine in accordance with the first construction comprises a vehicle running on caterpillar tracks 1 and having a power generating unit 2 and a driver's cab 3. The machine is motor driven in conventional manner. The power generating unit 2 and the cab 3 are supported on cross-tubes 4 and 5 which are extensible in order to vary the width of the machine. The ends of the cross-tubes 4 and 5 are mounted in side-beams 6 and 7 which are supported through hydraulic jacks 8 and 9 on side structures 10 and 11. Thus there is a pair of hydraulic jacks 8 connected between the beam 6 and side structure 10 and a pair of hydraulic jacks 9 connected between the beam 7 and structure 11. The side structures 10 and 11 are similar and are supported from the axles of the track wheels 12 and 13 on each side of the machine.

A conforming plate 15 is suspended from the cross-tubes 4 and 5 by arms 14, the suspension arrangement enabling a controlled lateral movement of the conforming plate relative to the tracks 1 by hydraulic jack 16 connected between the conforming plate and the side structure 11. It will be appreciated that the height of the conforming plate 15 can be controlled by simultaneous raising or lowering of the four jacks 8 and 9. The attitude, i.e., level or cant, of the conforming plate 15 transversely of the machine can be controlled by differential operation of the jacks 8 and 9. The longitudinal attitude of the conforming plate 15 can be controlled by differential operation of the rear jacks 8 and 9 and the front jacks 8 and 9. If the width of the machine is altered by adjustment of the cross-tubes 4 and 5, then the conforming plate 15 is changed for one appropriate to the new width of the machine.

In use of the machine a concrete mix is piled in front of the upturned front end of the conforming plate 15, the pile of concrete mix being continuously agitated by a vibrator (not shown) mounted on the front of the machine so that the mix is flowable. As the machine moves forward the concrete mix flows beneath the conforming plate 15, the undersurface of the conforming plate 15 slipping over the concrete mix so that the concrete bed thus formed has a smooth finish upper surface determined by the setting of the conforming plate through the jacks 8 and 9. The conforming plate is provided with side-headers 17 which confine the

concrete mix to beneath the conforming plate **15** and form the side edges of the concrete bed.

The basic lateral positioning and height control of the conforming plate is from datum wire **18** laid alongside the surveyed route which the machine is to follow. The datum wire **18** is stretched taut between supporting posts **19** (FIG. **3**) so that on a curve in the route it forms a series of chords **20** to the curve **21** parallel to the desired curve **22** for the adjacent edge of the concrete bed. The height of the datum wire **18** is set so that it follows any desired gradients which are to be incorporated in the upper surface of the concrete bed.

The tracks **1** of the machine are automatically steered from the datum wire **18** in conventional manner so that the machine follows with a somewhat coarse accuracy the desired route of the concrete bed. Having provided this coarse steering the fine control is provided by controlled lateral positioning and height adjustment of the conforming plate **15**. For this purpose, as shown in FIG. **4** forked probe **25** embraces the datum wire **18** for lateral positional control and forked probe **26** embraces the datum wire **18** for height control. The probes **25** and **26** are mounted at the ends of cranked lever arms **27** and **28** pivotally mounted at **29** and **30** on the conforming plate **15** and carrying short cross-bars **31** and **32** at their ends adjacent the conforming plate **15**. Thus upon relative lateral movement occuring between the conforming plate **15** and the datum wire **18**, the cross-bar **31** on the lever arm **27** will move in an arc indicated by arrows **33** and upon relative vertical movement occurring between the conforming plate **15** and the datum line **18**, the cross-bar **32** on lever arm **28** will move in an arc indicated by arrows **34**.

The movement of cross-bar **31** is sensed by a sensing unit **35** and the movement of cross-bar **32** is sensed by a similar sensing unit **36**. Each sensing unit as clearly shown in FIG. **5** comprises a pair of parallel air jets, one jet flowing between pipes **37** and **38** and the other jet flowing between pipes **39** and **40**. For the correct lateral and height positions of the conforming plate **15** relative to the datum wire **18** the cross-bars **31** and **32** are centered between the air jets of the sensing units **35** and **36**. If however there is a relative lateral movement between the conforming plate **15** and the datum wire **18**, the cross-bar **31** intercepts one or other of the air jets and this causes an output signal from the sensing unit **35** which causes operation of the jack **16** to move the conforming plate **15** laterally in the correct sense to re-center the cross-bar **31** between the air jets. Similarly relative vertical movement between the conforming plate **15** and datum wire **18** will cause an output signal from the sensing unit **36** to cause operation of the jacks **8** and **9** to move the conforming plate **15** vertically in the correct sense to re-center cross-bar **32** between the air jets of sensing unit **36**.

The transverse attitude control of the conforming plate is effected by a similar sensing unit **41**, which senses the position of a cross-bar **42** mounted at the lower end of a pendulum **43** pivoted at **44** on the conforming plate **15**. Thus, assuming that the conforming plate is to be maintained horizontal transversely, the cross-bar **42** is centered between the air jets when the conforming plate is horizontal and departure of the conforming plate from the horizontal will cause the cross-bar **42** to intercept one or other of the air jets. This causes the sensing unit **41** to produce an output signal to actuate the jacks **8** on one side or the jacks **9** on the other side of the machine to re-center the cross-bar **42**. It will be appreciated that if the jets are moved relatively to the conforming plate by rotation of the pipes **37** to **40** through a given angle about pivot **44**, a transverse cant of corresponding angle will be given to the conforming plate **15** by reason of the sensing unit **41** maintaining the cross-bar **42** centered between the air jets by the feed-back control to the jacks **8** and **9**.

For the longitudinal attitude control of the conforming plate a similar arrangement as that for the transverse attitude can be provided, but with the pendulum swinging longitudinally of the conforming plate **15**. Alternatively this could be controlled by separate probes at the front and rear of the conforming plate one probe controlling the rear jacks **8** and **9** and the other controlling front jacks **8** and **9**.

With the system so far described the lateral position and height of the conforming plate will follow the datum line **18** and thus the concrete bed would follow a route parallel to the chords **20** shown in FIG. **3**. However, particularly for laying a concrete bed which is to form the foundation for supporting the rails of a railway track, a much greater accuracy is necessary. Thus it is necessary for the route to follow the series of shorter chords **46** shown in FIG. **3**. To set up the datum wire **18** so that it follows the curve **21** as accurately as this entails a very elaborate and time consuming surveying operation. To avoid this, a programmed control system is therefore provided so that as the machine proceeds along the route a series of offsetting control movements relative to the datum wire **18** are fed to the conforming plate **15** and the lateral position of the conforming plate **15** therefore follows the shorter chords **46**. A similar programmed control system is provided for the vertical height control of the conforming plate **15** so that for example a gradient can be built into the surface whilst the wire **18** is maintained horizontal.

The programmed control for the lateral positioning of the conforming plate **15**, is achieved by a programmed adjustment of the sensing unit **35**, i.e., of the parallel air jets, about the pivot **29**, so that the consequent lateral movement of the conforming plate to maintain the cross-bar **31** centered between the jets will cause the necessary offsetting movement of the conforming plate relatively to the datum wire **18**. The programmed control of the vertical positioning of the conforming plate **15** is similarly achieved by a programmed adjustment of the sensing unit **36** about pivot **30**. A similar programmed control of the lateral attitude of the conforming plate **15** can be achieved by programmed adjustment of the sensing unit **41** about pivotal axis **44** so that as the machine proceeds along the track, the consequent canting of conforming plate **15** produces the required cant or banking of the concrete bed.

The programmed control for the lateral positioning of the conforming plate **15** will now be described in more detail with reference to FIGS. **5** and **6**. As can be seen in FIG. **5**, the pipes **37** to **40** of the sensing unit **35** producing the two air jets are mounted on frame members **48** and **49** secured to quadrant member **50**. Member **50** is mounted on a shaft **51** of an electric

motor 52, the motor shaft 51 lying on pivot axis 29 for the lever arm 27 so that energization of the motor causes rotation of the sensing unit 35 about axis 29. The energization of the motor 52 is controlled by a timer 54, the electric motor being geared so as to allow the shaft 51 to rotate through a very small movement over a period of seconds.

Referring now more particularly to FIG. 6, the control of the motor 52 via timer 54 is from a punched tape 55 having two channels, one for controlling rotational movement of senser unit 35 in one direction and the other controlling rotation of senser unit 35 in the opposite direction. The punched tape 55 is driven from spool 56 to spool 57 in synchronism with the movement of the machine and passes through sensor head 58 for one channel and sensor head 59 for the other channel. The sensor heads 58 and 59 each comprise aligned air pipes 60 and 61, the sensor head 58 being supplied with air along line 62 and the sensor head 59 being supplied with air along line 63. Thus each sensor head creates a jet of air from its pipe 60 which is obstructed by the tape except when a punched hole lies between the pipes 60 and 61. When a punched hole lies between the pipes 60 and 61, the air jet is detected by pipe 61 and causes an air signal or pulse to pass through to pressure sensitive unit 64 in the case of sensor head 58 and to pressure sensitive unit 65 in the case of sensor head 59.

When the pressure sensitive unit 64 detects a pulse this energizes timer 54 for a predetermined length of time to cause motor 52 to be energized for this length of time and therefore rotate the sensor unit 35 through a predetermined angle in one direction about axis 29. Similarly when pressure sensitive unit 65 detects a pulse this causes the motor 52 to rotate through the same angle but in the opposite direction.

Rotation of the sensor unit 35, for example clockwise as seen in FIG. 5 will cause the cross-bar 31 to intercept the left hand air jet between pipes 37 and 38 and this will be detected by pressure sensitive switch 66. Pressure sensitive switch 66 thus produces an electrical output signal which energizes a solenoid operated valve to actuate hydraulic jack 16 and thus move the conforming plate 15 in the direction so that the sensing unit 35 is moved to re-centralize the cross-bar 31 between the air jets. Similarly anti-clockwise movement of the sensor unit 35 will be detected by pressure sensitive switch 67, causing a consequential lateral movement of the conforming plate 15 so that the cross-bar is re-centered between the air jets of sensor unit 35.

The programmed control system for the sensor units 36 and 41 will be the same resulting in pressure sensitive switches corresponding to switches 66 and 67 producing the required control of jacks 8 and 9. The programmed control for the three sensing units 35, 36 and 41 is advantageously from a single tape with the appropriate number of channels, i.e. the appropriate number of lines of punched holes. A further channel or channels may provide a zeroing function so that back lash in the motor 52 may be counteracted.

As mentioned above, the movement of the tape 55 is synchronized to the movement of the machine. To counteract loss of synchronization, the tape drive to provided with a zeroing device 68 which allows the tape 55 to be driven so far and then cuts out the drive by operation of micro-switch 69. The drive of the tape cannot be re-started until the machine passes one of series of reference points for example on the datum wire 18. Thus if the tape is in exact synchronism with the movement of the machine, the microswitch 69 will be operated at precisely the same time as the machine passes the reference point so that there is no significant interruption in the tape drive.

Referring to FIGS. 7 and 8 the general construction of the slip form paving machine may be as shown in FIGS. 1 and 2.

The slip-form paving machine has a conforming plate 71 which skims the surface of the cement-concrete mix and which can be adjusted horizontally laterally of the machine by hydraulic ram connection 72 between the main body 73 of the machine and the conforming plate 71. Coarse guidance of the machine and hence of the conforming plate 71 is effected by guide wire 74 which is sensed by conventional probe 75. Since the guide wire 74 need only provide coarse guidance it need not be positioned with a high degree of accuracy and this minimizes surveying time.

The high accuracy, or fine control of the conforming plate 71 is through laser-beam 76 projecting from a pedestal mounted laser and shining onto sensing means in the form of a split photocell 77 mounted on the conforming plate 71. As can be seen from FIG. 8 the photocell 77 is adjustable vertically and horizontally relatively to the conforming plate by hydraulic rams 78 and 79 respectively.

For a give setting of rams 78 and 79 if, as the machine moves along its intended course under guidance from the wire 75, the conforming plate 71 moves to a position such that the laser-beam 76 is no longer centered on the photocell 77, feedback signals from the photocell 77 cause actuation of the rams 72 and/or 80 to adjust the conforming plate 71 by an amount and in the direction to re-centralize the beam 76 on the photocell 77. Thus a predetermined relationship between the photocell 77 and the laser beam 76 and hence between the conforming plate 71 and laser-beam 76 is maintained.

If the setting of the photocell 77 relative to the conforming plate 71 is purposely varied by actuating rams 78 and/or 79 consequent adjustment of the conforming plate 71 by jacks 72 and/or 80 to re-centralize the laser-beam 76 on the photocell 77 will vary the relationship between the beam 76 and the conforming plate 71. Thus, for example, if the actuation of rams 78 and 79 is controlled from a punched paper tape using fluidic control the conforming plate 71 can be made to follow a predetermined curved path relatively to a straight laser-beam.

Gradient and cant control can be built into the guidance system using attitude control systems in similar manner to that described with reference to FIGS. 1 to 6.

We claim:

1. A surface forming machine comprising, a conforming member for conforming a surface of a roadway as the machine moves along the roadway and which is adjustable along at least one direction relative to the machine, at least one follower means mounted for movement with the conforming member along said one direction for sensing a datum, sensing means responsive to said follower means to control the position along

said one direction of the conforming member as the machine moves along the roadway and being effective thereby to maintain the follower means centered with respect to the datum, and programmed control means arranged to be driven in synchronism with the movement of the machine along the roadway for moving the sensing means along said one direction relatively to the conforming member, whereby the consequent adjustment of the conforming member by the sensing means to restore the follower means to its centered position with respect to the datum follower means varies the relationship between the position of the conforming member and the datum.

2. A surface forming machine as claimed in claim 1, wherein the sensing means provides a pair of parallel air jets between which said datum follower means is centered, interception of either of said air jets by said datum follower means causing lateral adjustment of the conforming member by said sensing means to re-center the datum follower means between the air jets.

3. A surface forming machine as claimed in claim 1, wherein the conforming member is adjustable both laterally and vertically of the machine to set both the lateral position and vertical height of the conforming member with reference to a datum; said one follower means, said sensing means, and said programmed control means all being arranged to control the lateral position of said conforming member relative to the datum; said machine further including second follower means for sensing the datum and mounted for vertical movement with the conforming member, second sensing means responsive to said second follower means and arranged to cause vertical adjustment of the conforming member to thereby maintain said second follower means centered with respect to the datum, and second programmed control means arranged to move the second sensing means vertically relatively to the conforming member whereby the consequent vertical adjustment of the conforming member by the second sensing means to restore the second follower means to its centered position with respect to the datum follower means varies the relationship between the vertical position of the conforming member and the datum.

4. A surface forming machine as claimed in claim 3, wherein the second sensing means provides a pair of parallel air jets between which said second datum follower means is centered, interception of either of said air jets by the second datum follower means causing vertical adjustment of the conforming member by said second sensing means to re-center the second datum follower means between the air jets.

5. A surface forming machine as claimed in claim 1 wherein the conforming member is variable in its attitude transversely of the machine, said machine further including third datum follower means mounted for movement with the conforming member for sensing a datum determining the transverse attitude of the conforming member, third sensing means arranged to vary the transverse attitude of the conforming member to maintain the third datum follower means centered with respect to the datum, and third programmed control means arranged to move said third sensing means relatively to the conforming member, whereby the consequent transverse attitude adjustment of the conforming member to restore the third follower means to its centered position with respect to the datum causes it to vary its transverse attitude with respect to said datum.

6. A surface forming machine as claimed in claim 5, wherein said third datum follower means comprises a pendulum suspended to swing transversely of the conforming member and whose displacement in either direction from the vertical is detected by the third sensing means.

7. A surface forming machine as claimed in claim 6, wherein the third sensing means provides a pair of parallel air jets between which the pendulum is centered, interception of either of said air jets by the pendulum causing adjustment of the transverse attitude of said conforming member to re-center the pendulum between the air jets.

8. A surface forming machine as claimed in claim 1, wherein the conforming member comprises a plate adapted to conform a surface of a roadway by engagement of one of its faces with the surface and is variable in its attitude longitudinally of the machine, and wherein fourth datum follower means are mounted for movement with the conforming member for sensing a datum determining the longitudinal attitude of the conforming member, fourth sensing means arranged to tilt the conforming member longitudinally of the machine to maintain the fourth datum follower means centered with respect to the datum, and fourth programmed control means arranged to move the fourth sensing means relatively to the conforming member, whereby the consequent longitudinal tilting movement of the conforming member to restore the fourth datum follower means to its centered position with respect to said fourth datum follower means causes it to vary its longitudinal attitude with respect to said datum.

9. A surface forming machine as claimed in claim 8, wherein said fourth datum follower means comprises a pendulum suspended to swing longitudinally of the conforming member and whose displacement in either direction from the vertical is detected by said fourth sensing means.

10. A surface forming machine as claimed in claim 1, wherein said programmed control means has a programmed tape driven in synchronism with the movement of the machine along the roadway.

11. A surface forming machine as claimed in claim 10, wherein said programmed tape comprises a punched tape and the means for detecting a punched hole in said tape comprises a pair of nozzles between which the tape passes and between which an air jet flows when a punched hole lies between said nozzles.

12. A surface forming machine as claimed in claim 11, wherein said detecting means is arranged to produce an output signal each time a punched hole lies between the nozzles, the output signal causing energization of an electric motor to which the sensing means are connected for movement relatively to the conforming member.

13. A surface forming machine as claimed in claim 12, wherein a timer is energized by said output signal and causes energization of said motor for a predetermined time and thereby causes a predetermined movement of the sensing means relatively to the conforming member.

14. A surface forming machine as claimed in claim 11, wherein a pair of channels of punched holes is pro-

vided, each channel being sensed by respective detector means, one detector means causing rotation of the motor and thus movement of the sensing means relatively to the conforming member in one direction and the other detector means causing rotation of the motor and thus movement of the sensing means relatively to the conforming member in the opposite direction.

15. A surface forming machine as claimed in claim **10** wherein the tape is arranged to be driven in synchronism with the machine for a predetermined distance and is then stopped until an external zeroing signal is applied to recommence the tape drive.

16. A surface forming machine as claimed in claim **1** wherein the actuating means comprise hydraulic jacks controlled through solenoid operated valves by said sensing means.

17. A surface forming machine comprising, a conforming member for conforming a surface of a roadway as the machine moves along the roadway and which is adjustable relative to the machine, datum follower means mounted for movement relative to the conforming member for sensing a datum, sensing means responsive to said follower means to control the position of the conforming member as the machine moves along the roadway and being effective thereby to maintain the follower means centered with respect to said datum, and programmed control means arranged to be driven in synchronism with the movement of the machine along the roadway for moving the sensing means relatively to the conforming member, whereby the consequent adjustment of the conforming member by the sensing means to restore the follower means to its centered position with respect to the datum varies the relationship between the position of the conforming member and the datum in accordance with a predetermined program, the programmed control means being co-operable with control means spaced at intervals along the roadway to maintain the program in synchronism with the movement of the machine along the roadway.

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