Nov. 9, 1971 G. E. LONG 3,618,484

TRAVELING GRADE CONTROLLER

Filed Sept. 11, 1969

FIG. 1

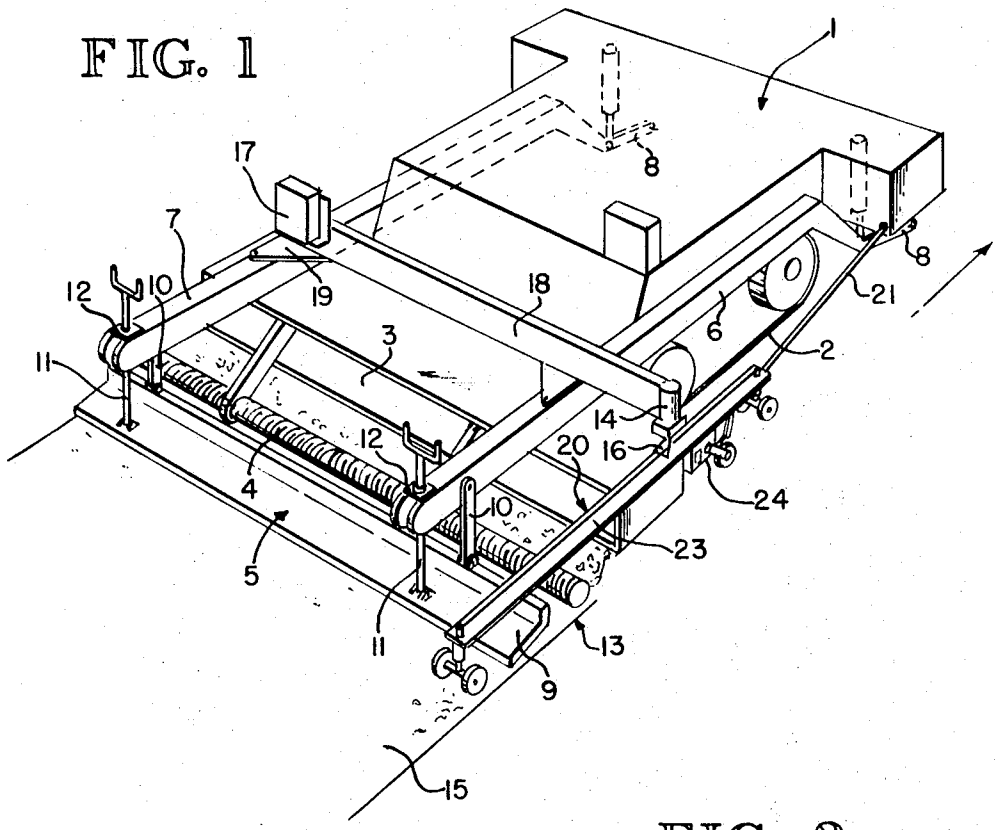
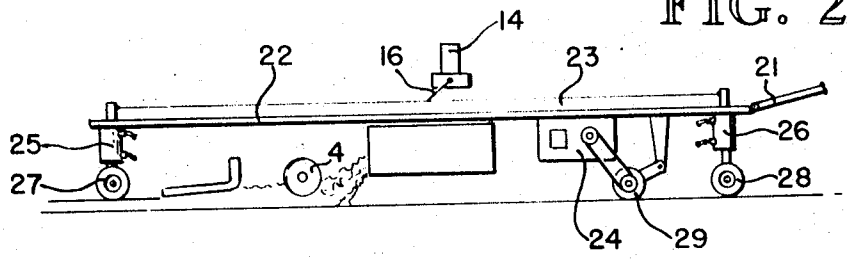


FIG. 2



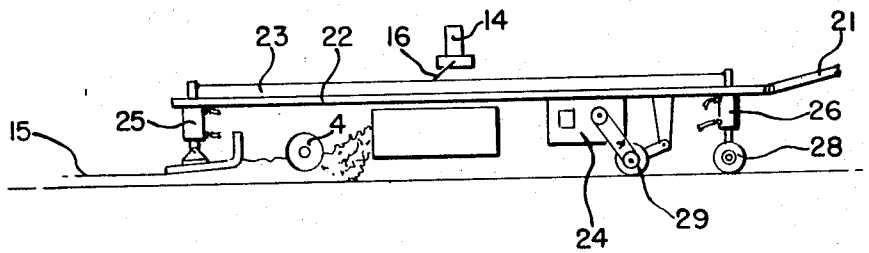


FIG. 3

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TRAVELING GRADE CONTROLLER

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U.S. Cl. 94—46 R 11 Claims

ABSTRACT OF THE DISCLOSURE

A device for providing a grade reading at any given instant along a given course for a grade sensing unit of a traveling machine, such as a paving machine. An elongated grade follower arm or beam, vertically adjustable at both ends, is towed independently or by the traveling machine providing a grade reference point in contact with the grade sensor device of the machine. One end of the arm or beam is controlled for elevation from a known datum such as the surface just prepared. The opposite end of the arm is controlled by a slope sensing device mounted on the elongated grade follower arm and is raised and lowered to maintain a desired slope between the opposite ends of the frame. The slope controller may be programmed according to a desired profile to obtain a vertical curve of close tolerance, for instance, in a paved highway.

BACKGROUND OF THE INVENTION

The present invention relates to an apparatus for controlling the position of implements such as paver screeds, earth levelers, finishers, earth-working implements and surface preparation elements which are mounted on traveling machines such as asphalt pavers, graders, and the like. More particularly, the present invention relates to a grade or elevational reference device which moves along a course of travel and which is continuously sensed by a grade sensor mounted on the traveling machine. The grade sensor produces a signal for controlling a paving screed or other implement on the machine.

In the building of paved roads it is necessary to match or relate the finished surface of the road to a predetermined grade line along its course and to provide a datum line which is related to the desired profile of the road in order to obtain either level courses and vertical curves. The general practice has been to provide the datum line by using a series of spaced hubs or grade stakes at one side of the course to be paved, finished, or leveled and to support a continuous taut wire on the stakes or hubs at the predetermined elevation and with the proper slope. For rough work, the taut wire is eliminated, but in any case of finishing to close tolerance, it is necessary to set the taut wire on grade and read from it constantly. In the instance of a paving machine, for example, a relatively sensitive sensing mechanism having a movable sensing element is mounted on the paver and rides on the taut wire to provide a constant signal indicating whether the paver screed is above or below the desired elevation at any particular instant. The grade signal is used in various ways to raise or lower the working element of an implement or change the angle of attack of a transverse screed to thereby cause it to seek the proper level.

Reference is made to U.S. Pat. No. 3,334,560 describing a control system for sensing a preset reference line, the control system being applicable to paving machines, graders, scrapers and related machinery. The disclosure of this patent is incorporated herein by reference.

The present invention provides a method and apparatus for providing a constant datum point to control the grade sensor of a traveling machine without the necessity of using grade stakes or taut wire as used in the prior art. The present invention provides a traveling grade line which advances with the machine by either being towed by the machine or moved by other means. The apparatus of the invention comprises an elongated grade follower arm which carries a taut wire or the like, the elevation of which is sensed by a grade sensor mounted on a paving machine or other implement. The traveling grade line is controlled independently of the machine so that the taut wire is always at the desired elevation and slope. One end of the grade follower arm is controlled for elevation by an established datum such as the surface just finished or paved in back of the machine. The opposite end of the grade follower is vertically adjustable and subject to the control of a slope sensor unit which maintains the follower arm and its taut wire at a predetermined slope parallel to the direction of travel of the paving unit. The slope of the grade follower arm may be programmed for slope change according to increments of forward travel. In this manner the vertical profile of a roadway may be programmed.

A primary object of the present invention is to provide a moveable grade datum point for constant reference by the grade sensor of a traveling machine for the purpose of controlling the movable working element of the machine without the necessity of installing grade stakes and/or a stationary grade wire.

Another object of the present invention is to provide a movable grade datum of the character described which may be programmed, such as by pre-printed tape or other such means, to provide a predetermined grade slope change rate according to increments of forward travel of the machine.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a paving machine utilizing the traveling grade controller of this invention;

FIG. 2 is a side elevational view of the apparatus shown in FIG. 1 with the addition of an odometer for controlling the slope sensor according to increments of forward travel;

FIG. 3 is a side elevational view of a modified version of the apparatus wherein the rear end of the grade follower arm is supported by the paving screed.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. 1 a self-propelled paving machine is shown in conjunction with the traveling grade reference controller. Although the present description of the traveling grade reference controller is made with reference to a paving machine the grade reference controller can be adapted to control the functions of a wide variety of moving vehicles or machines whose functions are related to a reference surface or datum and the motion of the vehicle or machine. Particularly, the traveling grade reference controller is useful in conjunction with paving machines, graders, scrapers and related machinery.

FIG. 1 shows the self-propelled paving machine in diagrammatic form with only the elements essential to the present invention being shown in detail. The machine consists of a frame and body portion 1 which is usually provided with forward propulsion means such as track members 2. The paving material, such as asphalt or other material capable of being laid down in a mat, is supplied to the paving machine 1 while it moves along its course in a manner well known to the art. The paving machine 1 includes the necessary mechanism for feeding the paving material through an opening 3 in the rear of the frame of the machine as the machine moves in a direction indicated by the arrow in FIG. 1. The details of this mechanism form no part of the present invention and are well known to the prior art. As the paving material issues from opening 3 during forward movement of the machine,

a pair of oppositely directed power driven distributing screws **4**, carried by the machine frame, spread a loose mat of the paving material on the roadway base over the entire width of the machine in front of the screed assembly **5**. Some machines of this type are provided with a tamping bar or vibrator (not shown) immediately in front of the traveling screed, the vibrator or tamper serving to compact the loose paving material which the screed further smooths and levels to a predetermined slope and thickness in a manner which will be described.

The connection of the screed assembly to the paving machine is provided on the rear end of two elongated draft beams **6** and **7**. The draft beams may be coupled to the forward end of the machine in any desirable manner such as by links **8**. The forward ends of beams **6** and **7** are independently vertically movable and are controlled, for example, by the means of double-acting hydraulic cylinders as shown, which operate in a conventional manner and which are controlled by the control system of the paving machine. Such means as reversible electric motors or rotary hydraulic motors may be used instead of hydraulic cylinders to perform the same function.

The screed assembly **5** comprises screed **9** which may be of many forms and designs. Essentially it comprises a transverse horizontal plate which rides directly on the top surface of the freshly laid mat of paving material. The screed **9** is connected to the rear end of each of the draft beams **6** and **7** by means of vertical supports **10** and adjustment screws **11**. Supports **10** are rigidly attached adjacent the end of each draft beam and the hand screws **11** pass through threaded collars **12** on the ends of the beams which permit the screws to be raised and lowered in a manner well understood in the art. Each end of the screed **9** is pivoted both to supports **10** and the bottom end of hand screw **11**. With this arrangement the screed **9** may be adjusted by hand screws **7** to vary the angle of attack of the screed with respect to a horizontal plane.

The manner in which the thickness of the mat of paving material, the level of the top surface thereof, and the transverse slope of the top surface is determined, is well known to those skilled in the art. The entire screed assembly **5** is supported directly on the top surface of the freshly laid mat of paving material. The screed assembly is coupled to the paving machine by means of draft beams **6** and **7** and is permitted to vary in vertical level and thus to float on the finished mat while following at a fixed distance behind the paving machine. The compacting and smoothing function of the screed is accomplished as the screed moves over the paving material deposited immediately in front of its leading edge. The level of each new portion of the mat surface may be considered to be determined jointly by the level of the subgrade and the surface of the mat portion behind the screed just previously laid. The angle of inclination of the screed is referred to as the angle of attack of the screed as indicated by reference numeral **13** in FIG. 1. For any particular condition or operation including the particular paving material and the desired thickness of mat, there is typically an equilibrium value of the angle of attack for which the mat surface extends horizontally in the direction of travel. This value of the angle of attack is referred to as the critical angle.

In the present illustrated paving machine, as is usually the practice in the art, screed **9** is torsionally flexible about its longitudinal axis and hand screw members **11** constitute independently operable means for adjusting the angle of attack at the respective end portions of the screed. Manipulation of the hand screws also permits the operator of the machine to control the transverse slope of the resulting mat. For example by increasing the angle of attack at both ends of the screed, the mat thickness is caused to increase substantially uniformly across the mat. By increasing the angle of attack at one end of the screed and decreasing it at the other end, the transverse slope of the surface can be varied without substantially affecting the

average thickness of the mat. In addition to the manual adjustment described, the draft beams, by which the screed assembly is attached to the machine, provide an additional means for controlling the angle of attack of the screed and thus the elevation and transverse slope of the mat produced. Each of the draft beams **6** and **7** may be independently raised and lowered at their forward ends by means of the double-acting cylinders shown. The angle of attack of either or both ends of the screed **9** may thus be varied by raising and lowering the forward ends of the beams. At a given screw adjustment for the type of paving material being used, and with the machine moving over a flat horizontal roadway there is a definite equilibrium mat thickness at which the angle of attack of the screed has a defined critical value. If the forward ends of the draft beams **6** and **7** are raised or lowered with respect to the machine, the critical value of the angle of attack is changed to produce a lesser or greater mat thickness. In the event that one or both sides of the machine enters a slight depression in the subgrade longer than the track or wheel base, the thickness of the mat remains the same providing no adjustment of screw members **11** or the forward end of the respective beam **6** or **7** is made. The finished mat in this case would thus reflect such a depression from a level plane. However, by a proper sensing mechanism the power cylinders on the forward ends of the beams **6** and **7** may be controlled to compensate for this depression by raising the front end of one or both of the draft beams to change the angle of attack of the screed and thus gradually increase the thickness of the mat or paving material as the screed passes over the depressed portion of the subgrade to be covered, thus maintaining the desired elevation of the mat. Likewise, the transverse slope of the mat may be controlled by raising or lowering the front ends of the draft beams **6** and **7** to, in effect, twist the screed **9** to increase the thickness of the mat on one side with the screed providing a gradual transition from one side to the other of the mat. Control systems compensating for an uneven roadbed beneath the paving machines and for maintaining differential angles of attack between the two ends of the screed are known. See, for example, the control system described in U.S. Pat. No. 3,334,560. The control system operates by sensing both the transverse slope between draft beams **6** and **7** and a reference grade datum and controlling power cylinders independently for raising or lowering the ends of draft beams **6** and **7**. In addition, the control system may be used to provide an accurate and sensitive means for gradually changing the transverse slope of the finished mat automatically according to a preset rate of change without the use of manual operation of screw adjusting means **11**. Such a slope programming system is described in detail in U.S. Pat. No. 3,334,560. The sensing system used to sense and control both the grade and transverse slope of the mat of paving material is comprised generally of a grade sensor unit and a slope sensor unit.

The grade sensor unit **14** functions to sense the location of a preset datum plane represented in this invention by the traveling grade reference controller. The grade sensor unit thus controls the grade or elevation of one side of the finished surface of the mat **15** being laid. The sensor unit **14** in and of itself forms no part of the instant invention. Reference may be had to U.S. Pat. No. 3,334,560 for a description of one type of grade sensor unit which may be used. In brief, the sensor unit comprises a grade follower or pickup **16** and a signaling device. In the present invention the grade sensing device **14** is positioned to contact a taut wire or other grade reference surface attached to the traveling grade reference controller as will presently be explained. Grade sensor **14** functions to control vertical movement of the forward end of draft arm **6** as shown in FIG. 1 to determine the angle of attack of one side of screed **9** to effect the proper elevation of one side of the mat. Thus, if the grade control side of the machine enters a depression in the sub-

grade, the sensor device signals the hydraulic cylinder attached to the forward end of beam **6** to raise it and thereby increase the angle of attack of that side of the screed so as to increase the thickness of the mat to compensate for the depression and thus maintain the desired elevation of the finished mat. The opposite reaction takes place if a rise is encountered by the machine instead of a depression. Once the paving machine moves out of the depression or rise the grade sensor signals the hydraulic cylinder to return to its normal control level. If the roadbed is level and parallel with the plane established by the taut wire draft arm **6** is maintained stationary and the critical or optimum angle of attack of the screed is maintained to lay down the desired mat thickness.

A pendulum type slope sensing unit **17**, details of which are described in U.S. Pat. 3,334,560, or other slope sensing device is used to maintain the desired transverse slope of the screed. The amount of transverse slope given to the finished pavement depends upon the difference between the angles of attack of the right and left ends of screed **9**. A transverse beam **18** positioned as shown in FIG. 1 extends between or is carried by draft beams **6** and **7**, this slope corresponding directly to the slope of the finished pavement. Transverse beam **18** is a rigid beam of any desired configuration and is supported directly on top of draft beams **6** and **7**. As shown in FIG. 1, each end of beam **18** may be provided with a flange plate **19** resiliently connected to the respective draft beam to allow for relative movement between the beams and to absorb some of the shock and vibration.

The slope sensor unit **17** either of the pendulum, accelerometer or other type, is mounted on the sensor beam. A pendulum unit, for example, includes a settable pendulum contact arm which operates between two leaf contact members and reflects relative movement between the pendulum arm and the frame of the sensor unit to accomplish the slope sensing and signaling functions. Means is thus provided for obtaining an electrical signal upon deviation from the desired slope of sensor beam **18**. Deviation in either direction from a preset slope actuates the hydraulic cylinder attached to the forward end of beam **7** in either direction to correct the slope of sensor beam **18**.

Traveling grade reference controller

The traveling grade reference controller is indicated generally by reference numeral **20** and is connected to paving machine **1** by linkage **21** as shown in FIG. 1. The traveling grade reference controller may be towed independently of the machine if desired. If it is connected to the machine as shown the linkage connecting the two must be sufficiently flexible to allow the grade reference controller to pivot freely.

The grade reference controller **20** comprises an elongated grade follower arm **22** extending at right angles to the paving screed **5**. A taut wire **23** is preferably stretched between opposite ends of arm **22** and attached to upstanding posts or the like thereon. The elevation and slope of the grade follower arm are controlled by vertically adjustable means mounted on opposite ends thereof. The rear end of the grade follower arm is vertically controlled from a known reference plane or datum such as the mat surface **15** just laid. The forward end of the grade follower arm rides on the subgrade surface and is caused to be raised or lowered by a slope controller **24**, to be described, mounted on the grade follower arm, the slope controller functioning to maintain a desired slope between the opposite ends of the grade follower arm. As shown in FIG. 1 and 2 double acting hydraulic cylinders **25** and **26** are mounted on the underside of grade follower arm **22** at opposite ends thereof. The moveable pistons of these hydraulic cylinders are provided with rollers or wheels **27** and **28** which contact the mat surface just laid and the subgrade, respectively. As shown in FIG. 3 the rear end of the beam **22** may be supported directly on screed assembly **5** as an alternative arrangement to the wheel **27**. The general operation of the slope sensor unit **24** is the same as the slope sensor unit **17** mounted on transverse beam **18** which is used to control the transverse slope of screed **9**. Any suitable slope sensor unit may be used, however, provided it functions in substantially the same manner. The signal output of slope sensor unit **24** is operatively connected to hydraulic cylinder **26** on the forward end of grade follower arm **22**. If the slope or tilt of follower arm **22** is not as desired, sensor unit **24** operates to raise or lower the forward end of the grade follower arm to adjust it to the desired slope. For example, if a 2% slope is desired, the grade follower arm **22** is initially tilted upward by action of the hydraulic cylinder **26** to that particular slope. The slope sensor unit is then set to maintain that slope. As the machine moves forward the slope sensor unit **24** maintains the slope between the two opposite ends of grade follower arm **22** at the 2% slope. The hydraulic cylinder **25** may be used to adjust the initial height of the rear end of the beam **22**.

If desired the slope sensor unit **24** may be programmed by pre-printed tape or other means according to a desired profile. It is frequently desirable to provide a uniformly increasing or decreasing slope or uniform rate of change of slope of the finished pavement. This may be programmed to effect a uniform rate of change of the slope setting of the slope control unit **24**. The operation of such a programming unit or system in conjunction with a slope sensing and control system is disclosed in detail in U.S. Pat. No. 3,334,560 and forms no part of the instant invention. In general, the programmer operates on the basis of the desired rate of change in terms of percent of slope change per given increments of forward travel of the machine. As shown in FIG. 2, an odometer wheel **29** is operatively connected to the slope sensor unit **24** and contacts the surface being paved. The odometer wheel senses the forward travel of the machine and actuates the slope between the ends of the grade arm follower at the programmed rate.

OPERATION

With reference to FIG. 1 the traveling grade reference controller is pivotally connected to paving machine **1** by linkage **21**. The rear end of the grade follower arm is positioned so that roller **27** rides on the surface of the pavement just laid which constitutes the grade reference datum. The forward end of the grade follower arm is adjusted by hydraulic cylinder **26** to the desired slope. The grade sensor element **16** of grade sensor unit **14** is positioned to contact the taut wire **23** indicating the desired grade reference point. As the paving machine progresses forward the grade sensor unit **14** continually senses the grade line indicated by the taut wire on the traveling grade controller and controls the operation of draft arm **6** as previously described in connection with the control system. At the same time slope sensor unit **24** operates to maintain the preset slope desired on the beam **22**. If the slope sensor unit **24** is provided with a programmer unit, the programmer unit operates to change the slope setting in either direction at the desired rate while the paving machine progresses forward.

The present invention provides a useful improvement for the control of grade and slope of machines such as paving machines, graders, scrapers or the like. The traveling grade controller is simple to operate and eliminates the necessity and expense of setting grade stakes or regularly spaced hubs at one side of the surface to be paved to obtain a predetermined elevation and slope of the paved surface. With the traveling grade reference controller, the required slope and elevation can be easily preset and the grade reference controller operated to control the machine accordingly.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of controlling a traveling surface preparation machine for preparing a continuous surface, said machine having a surface preparation element controllable in response to a grade control signal, comprising; (1) using the surface immediately prepared rearwardly of the surface preparation element as the machine moves forwardly as a datum point, (2) establishing a grade reference point at a controlled elevation relative to the datum point and forwardly thereof, (3) maintaining the elevation of the grade reference point at a predetermined slope between said datum point and said grade reference, (4) generating a grade control signal corresponding to the elevation of the grade reference point, and (5) controlling the surface preparation element responsive to the grade control signal to progressively prepare a surface according to the position of the grade reference point, whereby the slope of the resulting surface will correspond to the slope between the datum point and the grade reference point.

2. The method according to claim 1 including the step of programming a rate of change of the predetermined slope relative to increments of forward travel of the machine.

3. In a traveling surface preparation machine for preparing a continuous surface, said machine having a surface preparation element and power means for adjusting the elevation of the element in response to a grade control signal, a grade reference controller system comprising:

an elongated grade controller arm located adjacent said machine and extending longitudinally with respect to the direction of travel thereof for establishing a grade reference point at a given location along its length,

first support means connected to the rear end of the controller arm and maintaining said rear end at a fixed distance above the level of the surface immediately prepared by the surface preparation element as the machine moves forward, thereby establishing a datum point,

second support means connected to the front end of the controller arm and supported on the unprepared base surface forward of the surface preparation element,

slope sensing and signal means mounted on the grade controller arm for sensing the slope along the longitudinal axis thereof,

said second support means including means responsive to said slope sensing and signal means for vertically adjusting the elevation of the front end of the controller arm to maintain a predetermined slope between the datum point and said grade reference point,

grade sensing and signal means operatively connected to said power means and contacting the grade reference point on said grade controller arm for generating a grade control signal to maintain the surface preparation element at a predetermined elevation relative to the grade reference point, and

means operatively associated with said machine to move said grade controller arm with said machine.

4. The combination according to claim 3 including; programer means operatively connected to said slope sensing and signal means for increasing or decreasing said predetermined slope at a predetermined rate of change according to increments of forward travel of the machine.

5. In a traveling machine having a movable surface preparation element and power means for adjusting the elevation of said element with respect to a grade reference point, a grade reference controller system comprising in combination:

an elongated grade controller arm extending transversely of said surface preparation element and parallel to the direction of travel thereof,

means supporting one end of said arm at a predetermined distance above the surface immediately prepared by the surface preparation element as it moves forwardly,

vertically adjustable support means supporting the other end of said arm on the base surface forward of the surface preparation element for controlling the longitudinal slope of the arm,

grade sensing and control means carried by said machine and operatively connected to said power means to maintain said surface preparation element at a predetermined elevation, said grade sensing means including a sensor element contacting a point along the length of said grade controller arm defining a grade reference point, whereby vertical movement of the controller arm determines the vertical position of the grade reference point,

slope sensing and control means mounted on said grade controller arm and operatively connected to said adjustable support means for maintaining a predetermined slope between the opposite ends of said grade controller arm, and

means operatively associated with said machine for moving said grade controller arm with said traveling machine.

6. In combination with a paving machine having a torsionally flexible transverse screed, first and second draft arms connected at one of their ends to adjacent opposite ends of said screed and at the other ends thereof to said machine, and power means for independently raising and lowering the other ends of said draft arms for controlling the angle of attack of both ends of said screed independently, a traveling grade reference controller comprising:

an elongated grade controller arm extending substantially parallel to said draft arms,

first support means connected to the rear end of the controller arm and maintaining said rear end at a fixed distance above the level of the surface immediately paved by the screed as the machine moves forward, thereby establishing a datum point,

second support means connected to the front end of the controller arm and supported on the unprepared base surface forward of the screed,

slope sensing and signal means mounted on the grade controller arm for sensing the slope along the longitudinal axis thereof,

said second support means including means responsive to said slope sensing and signal means for vertically adjusting the elevation of the front end of the controller arm to maintain a predetermined slope between the datum point and said grade reference point, grade sensing and signal means operatively connected to said power means and including a sensor element contacting the controller arm at a point defining the grade reference point for generating a grade control signal to maintain one of said draft arms at a predetermined elevation relative to the grade reference point, and

means operatively associated with said machine to move said grade controller arm with said machine.

7. The combination according to claim 6 including a transverse sensor beam extending between and supported by said draft arms, a transverse slope sensing means mounted on said sensor beam operatively connected to said power means for sensing deviation of the transverse slope of said sensor beam from the horizontal plane and controlling movement of said power means to adjust the vertical position of the other of said draft arms to maintain the desired transverse slope of said sensor beam.

8. The combination according to claim 6 wherein said first and second support means each comprises:

double acting power cylinders mounted on the under-

side of the respective ends of the grade controller arm, and

roller means connected to the power cylinders, said roller means respectively contacting the surface immediately paved behind the screed and the unprepared base surface forward of the screed.

9. The combination according to claim **8** including a taut wire extending between upstanding posts on the opposite ends of the grade controller arm, said wire serving as a contact surface for said grade sensor element.

10. The combination according to claim **6** including; programer means operatively connected to said slope sensing and signal means for increasing or decreasing said predetermined slope at a predetermined rate of change according to increments of forward travel of the machine.

11. The combination according to claim **6** wherein:

said first support means includes a double acting power cylinder connected between underside of the rear end of the controller arm and said screed, and

said second support means including a double acting power cylinder connected between the underside of the forward end of the controller arm, and roller means contacting the unprepared base surface forward of the screed.

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