Nov. 4, 1941. R. W. BAILY 2,261,491

APPARATUS AND METHOD FOR MAKING CONCRETE ROADWAYS

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Fig. 3

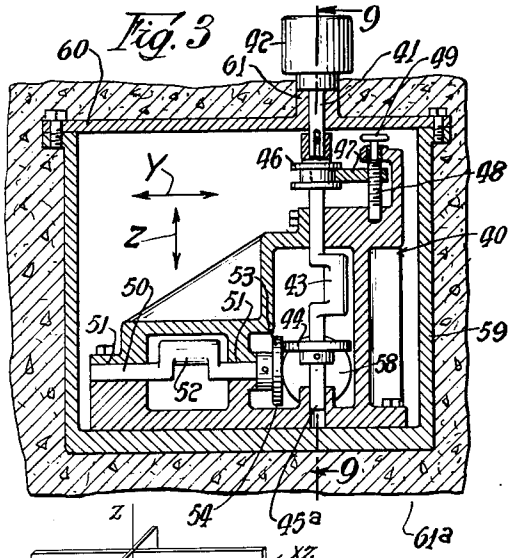
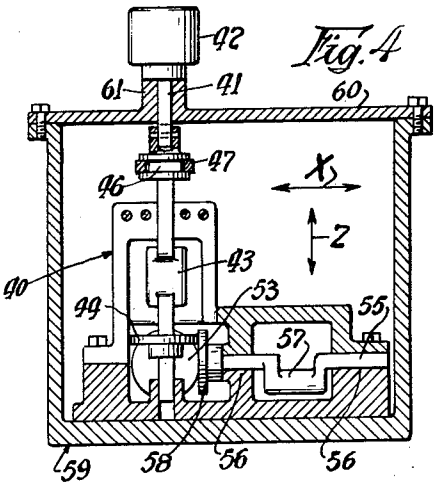


Fig. 4



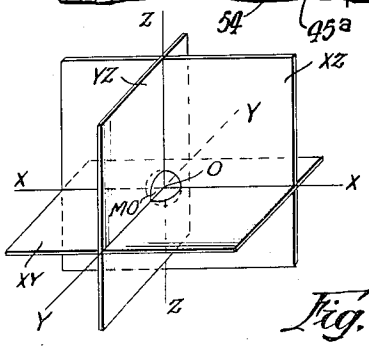


Fig. 1

Fig. 5

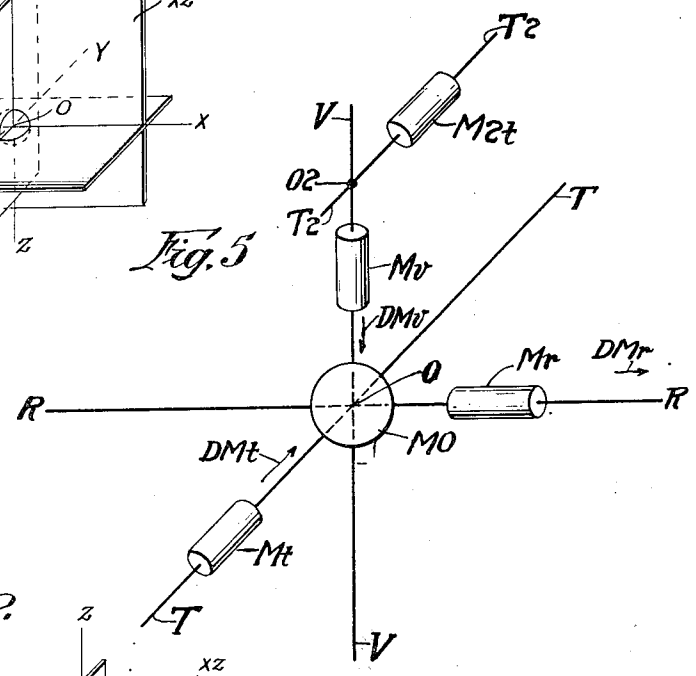
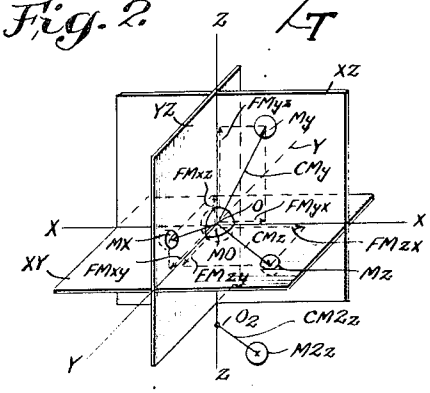


Fig. 2.



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Fig. 6

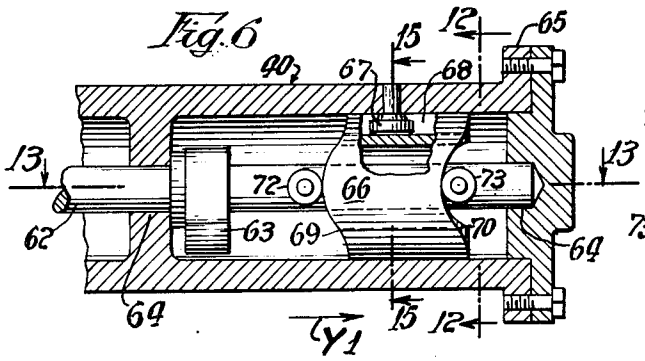


Fig. 7

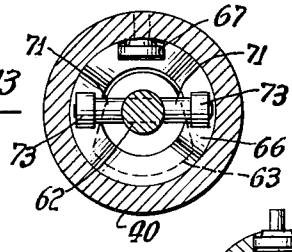


Fig. 10

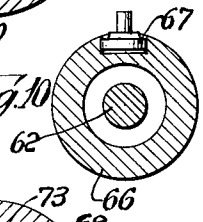


Fig. 8

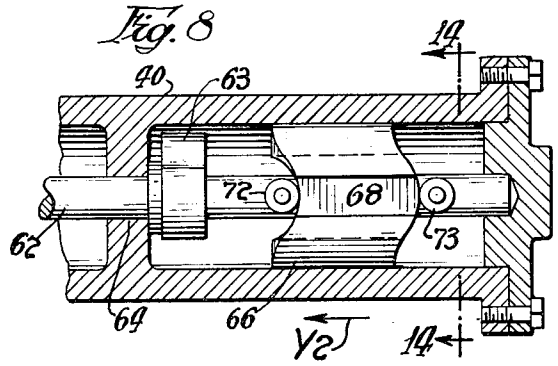


Fig. 9

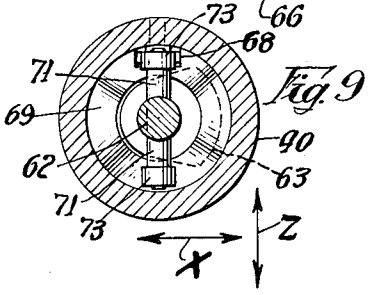


Fig. 11

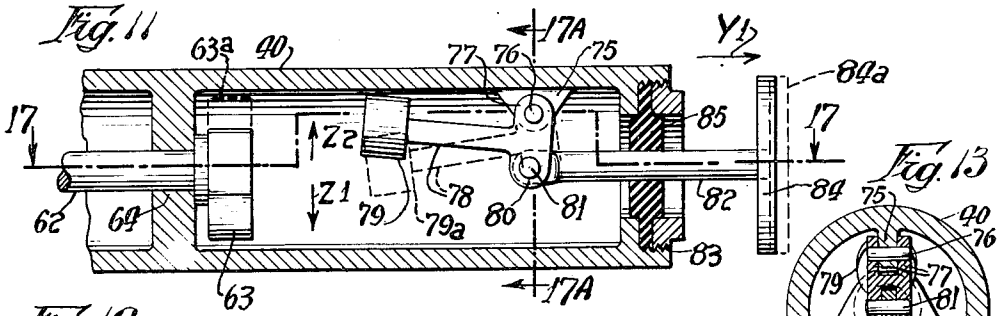


Fig. 13

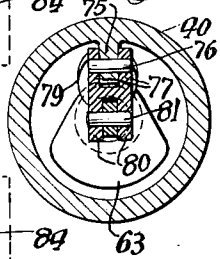
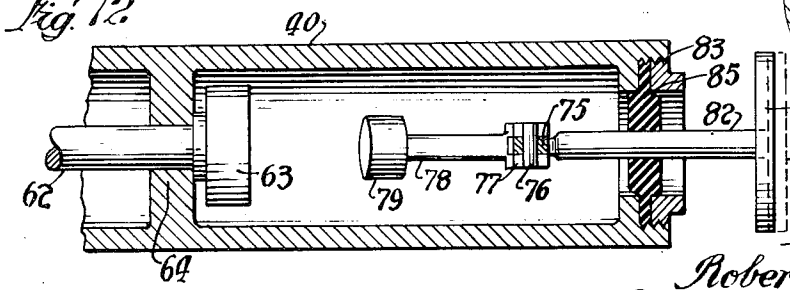


Fig. 12



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Fig. 14

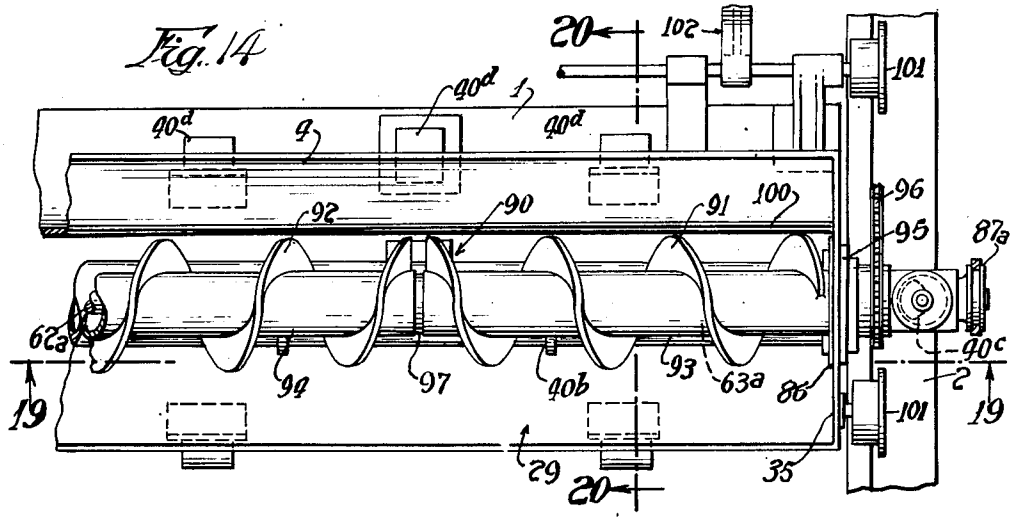


Fig. 15

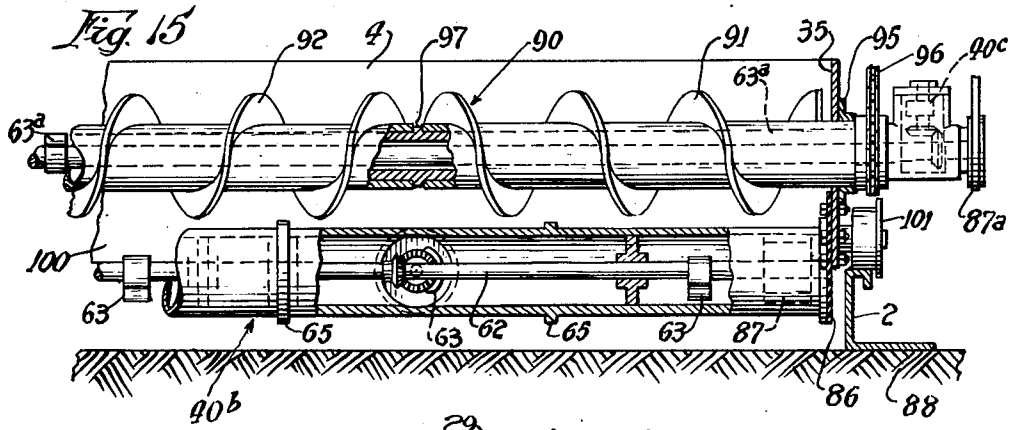
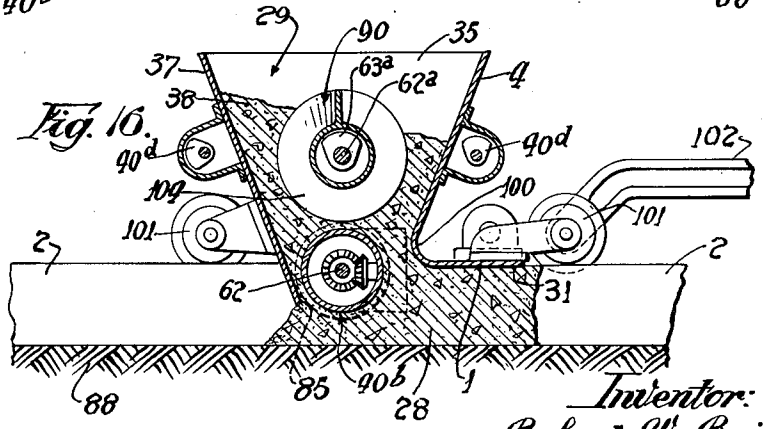


Fig. 16.



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APPARATUS AND METHOD FOR MAKING CONCRETE ROADWAYS

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Fig. 17

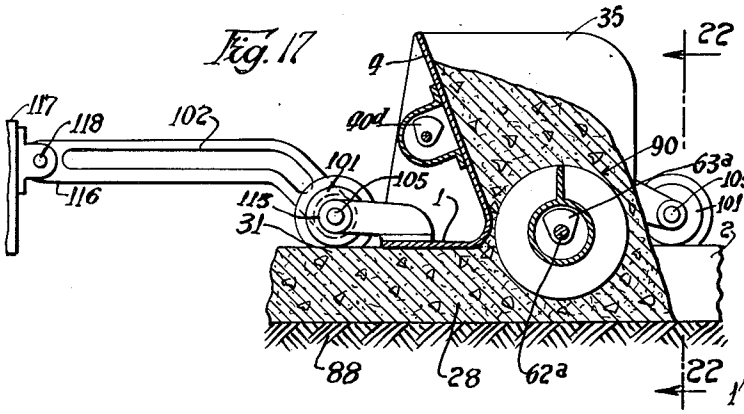


Fig. 19

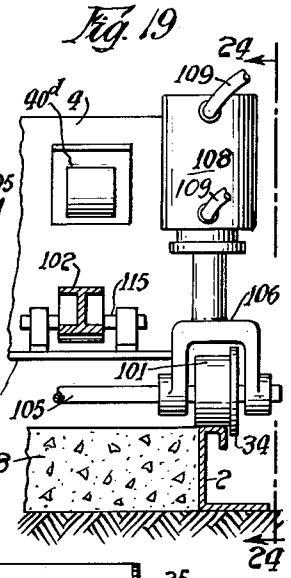
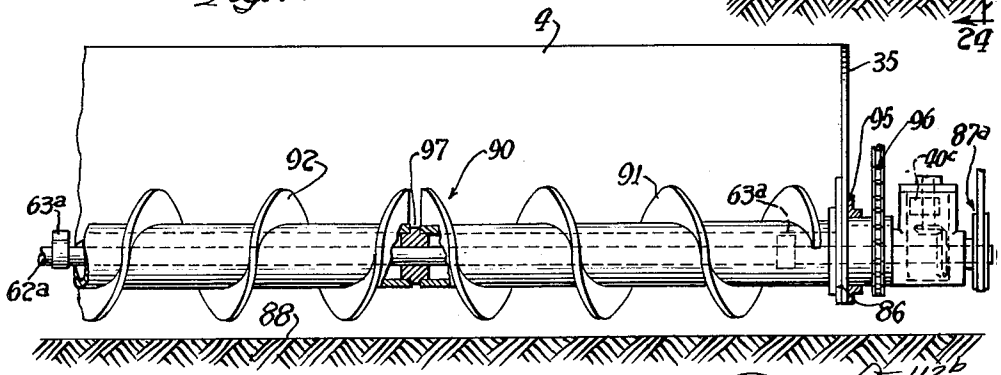


Fig. 18



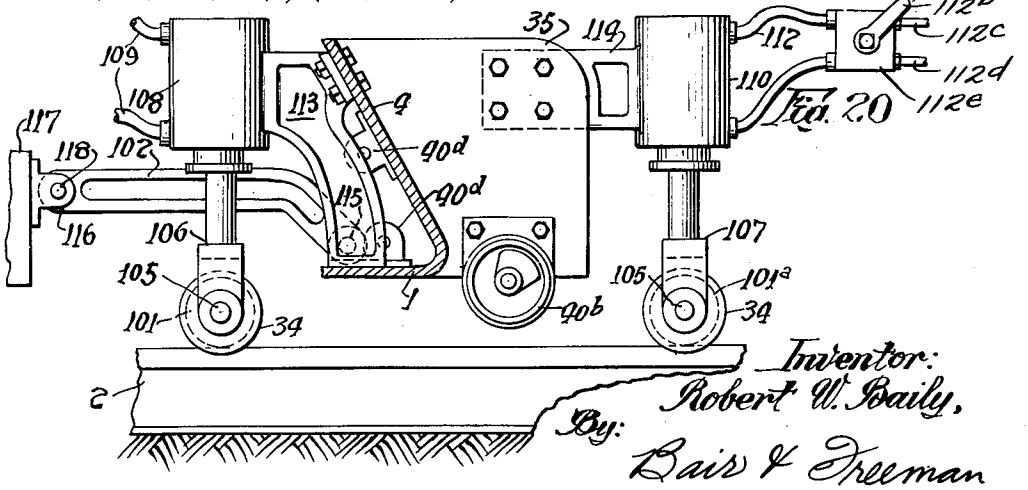


Fig. 20

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Patented Nov. 4, 1941 2,261,491

UNITED STATES PATENT OFFICE

2,261,491

APPARATUS AND METHOD FOR MAKING CONCRETE ROADWAYS

Robert William Baily, Narberth, Pa.

Application September 18, 1939, Serial No. 295,530

10 Claims. (Cl. 94—46)

My invention relates to apparatus and methods for striking off or leveling the surface of a concrete or similar types of roadways and vibrating the latter to cause the concrete to become exceedingly dense and homogeneous and rid it of entrapped air and water.

It is one object of this invention to provide a novel method and means for striking off the surface of a concrete roadway through the use of a strike-off board or screed and intensively vibrating the concrete by mechanism carried by the screed so that the concrete becomes a dense practically fluid mass readily flowing to places of least resistance and causing the elimination of air and water entrapped in the concrete. Other objects are to provide an improved vibrating means, a novel face plate, bins and other minor elements.

A further object of my invention is to treat any material, the particles of which move relatively to each other when vibrated.

A further object of my invention is to provide means in the bins or hoppers for conveying the material longitudinally in the bins, from the ends toward the intermediate zone, from one end toward the opposite end, or from the intermediate zone toward either end, so that the material as received in the bins may be kept uniformly disposed over the whole length of the bins, or concentrated at any locality or localities in the bins at the will of the operator.

Another object of my invention is to provide means for imparting to the material, vibrational forces having components in two or more planes, and in addition, so as to arrange the vibrator mechanisms producing these forces that one or more groups of the components may have frequencies or directions or both, differing from those of other of the components. My invention will permit me to apply these forces either externally to the material, or internally thereto, or both externally and internally simultaneously.

Another object of my invention is to provide means and a method to prevent the segregation or separation of the material before and during treatment.

This application is a continuation in part of my co-pending application Serial No. 428,747, filed February 15, 1930. Attention is also called to my co-pending applications Serial No. 514,124, filed February 7, 1931; Serial No. 256,249, filed February 13, 1939; Serial No. 74,114, filed April 13, 1936; Serial No. 166,822, filed September 7, 1937; Serial No. 114,877, filed December 8, 1936; and Serial No. 228,625, filed September 6, 1938.

Referring to the accompanying drawings:

Figure 1 is a diagrammatic perspective view of three basic-non-coincident axes combined with three non-coincident planes;

Figure 2 is a diagrammatic perspective view showing non-coincident axes and the three planes containing pairs of these axes, with vibratory out-of-balance weights rotating on each axis.

Figure 3 is a transverse vertical section of a form of my apparatus;

Figure 4 is a transverse sectional view on the line 9—9 of Figure 3;

Figure 5 is a diagrammatic perspective view showing four non-coincident axes with weights reciprocating on each axis;

Figure 6 is a vertical cross sectional view of another form of my apparatus;

Figure 7 is a horizontal cross sectional view taken on the line 12—12 of Figure 6;

Figure 8 is a vertical cross sectional view taken on line 13—13 of Figure 6 except that shaft 62 has rotated 90°;

Figure 9 is a vertical cross sectional view taken on line 14—14 of Figure 8;

Figure 10 is a vertical cross sectional view taken on line 15—15 of Figure 6 with certain parts of Figure 6 omitted;

Figure 11 is a vertical cross-sectional view of another form of my apparatus;

Figure 12 is a transverse section taken on line 17—17 of Figure 11;

Figure 13 is a vertical cross sectional view taken on line 17*a*—17*a* of Figure 11;

Figure 14 is a top plan view of another form of my apparatus;

Figure 15 is a vertical cross-sectional view taken on the line 19—19 of Figure 14;

Figure 16 is a vertical cross-sectional view taken on the line 20—20 of Figure 15;

Figure 17 is a vertical cross sectional view of a modification of the apparatus of Figure 14; and

Figure 18 is a vertical cross sectional elevational view taken on the line 22—22 of Figure 17;

Figure 19 is an elevation view of another form of my apparatus;

Figure 20 is a partly sectional elevation view taken on the line 24—24 of Figure 19.

Figure 2 is a diagrammatic perspective view of one form of my vibratory mechanism showing a point of origin O through which passes, horizontally right and left, the axis X—X, and

toward and from the observer the horizontal axis Y—Y, and vertically the axis Z—Z. The plane X—Y is horizontal, containing point O and the axes X—X and Y—Y. The plane X—Z is vertical, containing point O and the axes X—X and Z—Z. At an angle to the plane X—Z is the vertical plane Y—Z containing point *o* and axes Y—Y and Z—Z. The mass MO has its center of gravity at O.

Revolving about O on axis X—X with its center of gravity in plane Y—Z, I provide the mass M*x*, which exerts the centrifugal force CM*x* on mass MO. This force CM*x* may be resolved into the components FM*xy* parallel to axis Y—Y, and FM*xz* parallel to axis Z—Z.

Revolving about O on axis Y—Y with its center of gravity in plane X—Z, I provide the mass M*y*, which exerts the centrifugal force CM*y* on mass MO. This force CM*y* may be resolved into the components MF*yx*, parallel to axis X—X, and MF*yz*, parallel to axis Z—Z.

Revolving about O on axis Z—Z with its center of gravity in plane X—Y, I provide the mass M*z*, which exerts the centrifugal force CM*z* on mass MO. This force CM*z* may be resolved into the components FM*zx*, parallel to axis X—X, and FM*zy*, parallel to axis Y—Y.

In the positions as shown in Figure 2, components FM*xy* and FM*zy* are parallel and assist each other. The same is true of components FM*yx* and FM*zx*. Likewise FM*xz* and FM*yz* are parallel and assist each other.

Were mass M*y* below axis X—X but still on the same side of plane Y—Z, then forces FM*yx* and FM*zx* would still be parallel and assisting each other. But while force FM*yz* would still be parallel to FM*xz*, it would be opposite in direction and the lesser of the two would reduce the effect of the other. If equal, the resultant would be zero.

In any case it is seen that the center of gravity O of mass MO would oscillate in a path determined by the magnitudes, speeds of rotation and directions of the various forces CM*x*, CM*y* and CM*z* acting upon it.

If about another point of origin O2 on axis Z—Z, distant from point O, I provide a mass M2*z* revolving about the axis Z—Z, the centrifugal force CM2*z* exerted on point O2 will introduce still another force on mass MO and modify its previous path of travel.

The angles the planes XY, XZ and YZ make with each other may be varied.

The foregoing explanation of forces related to three principal, non-parallel but intersecting axes serves to simplify the descriptions following, relating to the apparatus of Figure 1 through 18. References to force components X, Y and Z will be understood to correspond to the explanation given of Figures 1, 2 and 5.

Figures 3 and 4 show another form of my apparatus. The housing **40** carries the shaft **41** associated with means **42** for rotating shaft **41**. Means **42** may be on the order of the apparatus shown in my United States Letters Patent No. 1,876,271. In housing **40** on shaft **41** I provide the out-of-balance weight **43**, below which is the friction drive disc **44**, with the end **45** of shaft **41** engaging the bearing **45***a*. Shaft **41** has the spool **46** engaging arm **47** which travels on screw **48** having handle **49** by which combination shaft **41** and its disc **44** may be raised or lowered.

In Figure 3, housing **40** also carries shaft **50** at an angle to shaft **41**, and running in bearings **51** and having out-of-balance weight **52**. One end of shaft **50** terminates in disc **53** which engages and is propelled by disc **44**. If disc **44** revolves at a uniform rate, the speed of rotation of disc **53** and the out-of-balance weight **52** will be decreased by adjusting disc **44** closer to the circumference **54** of disc **53**.

Opposite direction of adjustment of disc **44** toward center of disc **53** will increase the speed of shaft **50** relative to the speed of shaft **41**.

In Figure 4 the housing **40** carries shaft **55** at an angle both to shaft **41** and shaft **50**, and running in bearings **56** and having out-of-balance weight **57**. One end of shaft **55** terminates in disc **58** which engages and is propelled by disc **44** on shaft **41**. Speed of rotation of shaft **55** is adjusted in the same manner as that of shaft **50** of Figure 3.

Rotation of out-of-balance weight **43** imparts to the housing **40** forces having components in directions of axes X and Y. Rotation of out-of-balance weight **52** will impart to the housing **40**, forces having components in directions of the axes X and Z. Rotation of out-of-balance weight **57** will impart to the housing **40** forces having components in directions of the axes Y and Z. One or two of out-of-balance weights **43**, **52** or **57** may be omitted, if desired.

In Figures 3 and 4, I show the housing **40** associated with and attached to the member **59**, which may have the cover **60** provided with the gland **61**.

In Figure 3 I show housing **40** at least partially immersed in material **61***a*. Since the housing **40** has vibrations in directions of all three axes X, Y and Z, and since member **59** (and cover **60**) has imparted to it similar vibrations, the material **61***a* will receive force components in the same direction and rates as those imparted to the housing **40**.

Obviously, the rotative means at **42** of Figures 3 and 4 may, instead of being associated with shaft **42**, be associated with shaft **50** or shaft **55**. I may elect to utilize any of the combinations set forth against Figure 2 to impart vibrations to the housing **40**, and housing **40** may be associated with apparatus other than member **59**.

Reciprocating weights as in Figure 5 or Figures 11–12 may be used with any or all shafts **41**, **50** and **55**, in which case any or all out-of-balance weights **43**, **52** or **57** may be retained or omitted.

One or more housings **40** may be associated with housing member **59**.

Figure 5 is a diagrammatic perspective view of another form of vibratory mechanism showing a point of origin O through which passes horizontally, right and left, the axis R—R, and toward and from the observer the horizontal axis T—T, and vertically the axis V—V. The mass MO has its center of gravity at O. On axis R—R I provide the reciprocating mass M*r* with its center of gravity on axis R—R. On axis T—T I provide the reciprocating mass M*t* with its center of gravity on axis T—T. On axis V—V I provide the mass M*v* with its center of gravity on axis V—V.

As shown in Figure 5, the mass M*r* is traveling in direction DM*r* with acceleration or deceleration due to a connection between M*r* and Mo, and mass M*r* will therefore exert on mass Mo a force in the direction of DM*r* or opposite thereto. Likewise mass M*t* will, through a connection therewith, exert a force on Mo in the direction of DM*t* or opposite thereto. In the same fashion M*v* will through a connection therewith, also exert

a force on Mo in the direction of DM*v*, or opposite thereto.

It is seen that the center of gravity O'' of mass Mo will oscillate in a path determined by the magnitudes, frequencies and directions of the forces DM*r*, DM*t* and DM*v* acting upon it.

If on axis V—V at another point of origin O2 I provide the axis T2—T2, and a reciprocating mass M2*t* having its center of gravity on T2—T2, still other forces will be exerted on mass Mo to modify its previous path of travel.

The angles between the axes R—R, T—T, T2—T2 and V—V may be varied.

Obviously I may combine a part or all of the system of Figure 5 with part or all of the system of Figure 2 and Figures 11 and 12, and may arrange pluralities of parts, or all of either, or both systems to act in various ways on mass Mo and thereby obtain any desired movement of the mass Mo.

The masses M*x*, M*y*, M*z* and M2*z* of Figure 2 may be varied simultaneously or individually as to their mass, their distance from their respective axes, and their speed of rotation about their axes. Likewise the masses M*r*, M*t*, M*v* and M2*t* may be varied simultaneously or individually as to their mass, their frequencies of reciprocation and the lengths of their paths of reciprocation. The directions of the accelerations or decelerations DM*r*, DM*t*, DM2*t* and DM*v* may be selected at will.

In Figures 6 through 10, I show another arrangement of my apparatus.

Shaft **62** is actuated by rotative means not shown, and has the out-of-balance weight **63**. Shaft **62** runs in bearings **64** of housing **40**, which is also provided with laterally extending faces **65**. I provide the reciprocable weight **66** suitably carried in the housing **40** and arranged for axial movement therein. Housing **40** carries roller **67**, which engages slot **68** of weight **66**, preventing rotation of weight **66** in housing **40**. Weight **66** has cam-faced ends **69** and **70**. Shaft **62** has arms **71** carrying cam rollers **72** and **73**. Rollers **72** engage cam-face **69** and rollers **73** engage cam face **70**. As shaft **62** is rotated, it will through rollers **72** move weight **66** to the right, as in Figure 6, in direction of arrow Y—**1**. As shaft **62** rotates another 90 degrees, rollers **73** will reciprocate weight **66** to the left as in Figure 8, in direction of arrow Y—**2**. As rotation of shaft **62** continues, weight **66** will reciprocate, under the conditions shown in Figures 6 and 8, through two complete cycles for each revolution of shaft **62**. The housing **40** will have imparted to it by rotation of out-of-balance weight **63**, vibrations in directions of the axes X and Z of Figure 9, and in directions of the axis Y of Figures 6 and 8. Contact with housing **40** will impart to a material, force components in the same directions and rates as exist in housing **40**.

In Figures 11, 12 and 13 I show another arrangement of my apparatus. Shaft **62** is actuated by rotative means not shown, and has the out-of-balance weight **63**. Shaft **62** runs in bearing **64** of housing **40**. In housing **40** I provide the boss **75** carrying the pin **76** engaging the boss **77** of the arm **78** which carries the inertia weight **79**. In boss **80** of arm **78** and in a plane perpendicular to axis of shaft **62** and passing through pin **76**, I provide the pin **81** engaging the vibrator plunger **82** which extends approximately parallel to the shaft **62** through the end **83** of housing **40**. Plunger **82** terminates in disc **84** beyond the end **83** of housing **40**. End **83** is provided with gland **85** suitably secured in end **83**, and plunger **82** is carried in gland **85**, which may be of elastic material engaging plunger **82** of rigid material supporting slidably plunger **82** and deflecting with the movement of plunger **82**.

With shaft **62** rotating and out-of-balance weight **63** in downward position shown, weight **63** will impart to housing **40**, movement in direction of axis arrow Z—**1**. Weight **79** will be simultaneously, due to its inertia, at the upper position indicated in solid lines, and through its mechanism, disc **84** will be closest to end **83**.

As weight **63** rotates through 90° to position **63***a*, it imparts to housing **40**, motion in the direction of axis arrow Z—**2**. Weight **79** will simultaneously, due to its inertia, arrive at its lower position indicated in broken lines at **79***a*. Pin **81** will travel toward end **83**, moving plunger **82** in the direction of axis arrow Y—**1** and disc **84** to its position indicated by broken lines at **84***a*. Completion of one revolution by out-of-balance weight **63** will return the parts **78**, **79**, **80**, **81**, **82** and **84** to their original positions as one cycle of movement, reciprocating in directions parallel to axis Z. During the same cycle the forces exerted by out-of-balance weight **63** causes housing **40** to vibrate in directions along axes X and Y. Material in contact with housing **40** and disc **84** will have imparted to it, vibrations having components along axes X, Y and Z, and at a plurality of rates of frequencies.

In Figures 14, 15 and 16 I show another arrangement of my apparatus in which I have applied the mechanisms described in Figures 2 through 10, to the apparatus shown, and where possibly I have utilized in Figures 14, 15 and 16 the same reference characters as I utilized in other figures. Supporting medium **88** carries side forms or fixed means **2**. **1** is a screed, **29** is a hopper carried on wheels **101**, and having walls **4** and **37** and containing concrete **38**. The apparatus travels on side forms **2**.

In Figures 14, 15 and 16 I use the vibrating housing **40**—*b* which has the parts of housing **40**, Figures 3 through 10. Housing **40**—*b* may be located anywhere with relation to bin **29** but for convenience in Figure 16 I have located housing **40**—*b* adjacent the lower orifice **85** of bin **29**. Housing **40**—*b* is sustained by end **35** of bin **29** by means of elastic connections **86** intended to dampen the transmission of vibrations from housing **40**—*b* to bin **29** or other parts of the mechanism or to the forms or other structures associated with the material, and to allow free vibration of housing **40**—*b*. Housing **40**—*b* is associated with rotative means **87** rotating shaft **62** which carries out-of-balance weights **63**. Housing **40**—*b* may contain one or more mechanisms as described against Figures 2 through 10, and may be provided with one or more faces **65**.

Above housing **40**—*b* or elsewhere as convenient, I provide the conveying mechanism **90** which for convenience I have shown as twin screws **91** and **92**, arranged on their hollow shafts **93** and **94**. Shaft **93** extends through bin end **35** running in gland **95** and revolved in either direction by power mechanism **96**. Gland **95** may be of rubber and thus be resilient to afford vibration damping means for damping the transfer of vibrations to carriage parts, forms, or other structures associated with the material. Hollow shaft **94** is rotatably associated with shaft **93** at **97** and is rotated by means not shown, in a manner similar to power means **96**. Shafts **93** and **94** may be provided with shafts **62***a* carry-

ing out-of-balance weights 63*a* rotated by rotative means 87*a*. Shafts 93 and 94 may be provided with vibrating mechanisms 40—*c* which have the parts of housing 40, Figures 3 through 7. Wall 4, through cylindrical or tubular portion 100, is associated with screed 1. Walls 37 and 4, and ends 35, of bin 29, and the screed 1, may be associated with vibration mechanisms 40—*d*, as described against Figures 3 through 9. Wheels 101 may be provided for engagement with fixed means 2, forming a carriage for bin 29 and its associated apparatus, with propulsion means at 102 of Figures 14 and 16. Elastic means, not shown, may be interposed between the bin 29, the screen 1, and the fixed means 2, for damping the transmission of vibrations from the bin 29 or the screed 1 or associated devices, to carriage 101 or fixed means 2. In lieu of carriage 101 as shown, other carriage or propulsion means not shown may be provided. Screed 1 may be arranged not to make contact with fixed means 2.

In the operation of the apparatus described against Figures 14, 15 and 16 I show in Figure 16 material 38 to be treated deposited in bin 29, with its upper level preferably maintained at an elevation above portion 104 of screws 91 and 92. Should the material be not satisfactorily disposed through the length of bin 29, it may be conveyed longitudinally of the bin in either direction or in both directions by proper manipulation of screws 91 and 92. If desirable, the screws 91 and 92 may impart vibrations to the material to render it plastic, or to prevent segregation, or to expel entrapped air and surplus water, to condense and improve the material, or to cause particles of the material to move relatively to each other. These objects may be supplemented or assisted or otherwise attained by imparting to the material, vibrations from the walls of the bin 29, or from the screed 1, or from the vibrator 40—*b* in the lower orifice 85 of the bin, or by any combination of manipulation of the parts.

Vibrator 40—*b*, 40*c*, or a duplicate thereof, may be located below and before the orifice 85 of bin 29, or before, below or behind screed 1.

In the arrangement shown in Figures 14 through 16, the material 38 will, by force of gravity assisted by vibrations, pass downwardly through bin 29, past screws 91 and 92, thence past vibrator 40—*b*, and be deposited on supporting medium 88. The material 38 shown at location 28 will then be acted upon by the screed 1, either to vibrate the material, or to strike it off to approximately the desired surface elevation, or both.

While I have indicated the apparatus as a unitary structure, I may divide it into a plurality of parts, whereby the bin or its associated devices may be operated separately from the other parts of the apparatus, or in conjunction with other equipment. Likewise any part of the apparatus may be arranged for adjustment in any direction, whereby the distance between the final means 2 may be varied, or the finished surface 31 of the material may be left at any elevation or having any desired contour or crown, and whereby the material may be constructed in a plurality of strata or whereby a variety of materials may be deposited simultaneously or in any sequence.

In Figures 17 and 18 I have shown another form of my apparatus, in which I have omitted the front face 37 and one vibrator housing 40—*d*, of Figure 16, moving conveying mechanisms 91 and 92 down to the position formerly occupied by vibrator 40—*b* of Figure 16, so that my apparatus may be used in conjunction with a roadway paving device to distribute, level and treat the paving material 28 prior to its treatment by other appliances and apparatus.

Vibrator mechanisms delivering vibrations having vectors in a plurality of non-parallel intersecting planes are associated with the walls of the bins for vibrating them; vibrators are associated with the screed portion for vibrating it; vibrator mechanisms are associated with the conveying mechanism, and with the vibrating elements in the lower orifices of the bins. I may utilize any of the parts or combinations of any of the parts of the apparatus without reference to the parts which may be omitted.

I have found that when a material such as concrete is placed in a bin or on a supporting medium, and the material is pushed or conveyed laterally over the supporting medium in the absence of vibration, the material becomes segregated, the larger particles of aggregate working to the surface of the material in motion, and finally emerging entirely from the mixture, rolling freely down the advancing slope or surface of the mixture.

I have found that where a properly operated distributing device, which may be a horizontal revolving screw, is propelled laterally against a quantity of concrete, such as a batch of concrete which has been dumped from the mixer upon the subgrade of a roadway, and if the lower parts of the screw or distributing device are maintained at approximate finished grade line, the pile of concrete will be uniformly distributed across the subgrade between the forms and the resulting surface will be approximately at or above or below the tops of the forms, as desired. I have also found that the larger particles of aggregate are concentrated in the top stratum of the layer of material, the upper portions of such particles being exposed at the surface of the material. I have also found that when I propel a horizontal vibrating member laterally, at least partially immersed in the material, the impact of the member against the exposed larger particles may eject and expel many of those particles entirely out of the mixture.

I have also found that in concrete, when vibrated, the larger particles of aggregate tend to sink to the lower strata of the mixture, the mortar rising into the upper strata where there is created a deficiency of the larger particles.

I have also found that when concrete in a bin or on a supporting medium is pushed or conveyed laterally, and simultaneously subjected to vibration, the concrete remains properly mixed, the larger particles remaining uniformly distributed throughout the mixture. This part of my invention is thus described.

A part of my invention is the utilization of a leveling and distributing device, of which a horizontal revolving screw is one type, and vibrating the device thereby maintaining the proper distribution of the larger particles throughout the mixture. With this device I may also associate other vibrating means whereby the concrete deposited on the road bed is adequately compacted and condensed.

In treating the material in the bin, I may accelerate, retard or halt the travel of the bin or bins, in order that the contained material may receive the desired vibratory treatment prior to

or during the deposit of the material upon the supporting medium.

In Figures 19 and 20 I show means for adjusting the elevation of my apparatus with respect to the tops of the side forms 2 and material 28.

Coacting with the axles 105 I provide the connecting rods 106 on the rear wheels 101 and connecting rods 107 on the front wheels 101—*a*. Rods 106 are operated in cylinders 108 attached to plates 1 and 4. Hydraulic power to move rod 106 relative to cylinder 108 is supplied through conduit 109 from a controlling and supply source not shown. Rods 107 are operated in cylinder 110 by hydraulic power supplied through a controlling and supply source similar to 112—*a*, through conduits 109. Cylinder 108 is attached to screed 1 and plate 4 by bracket 113. Cylinder 110 is connected to wing plate 35 by bracket 114. Conduits 112 and 112—*e* lead from cylinder 110 to controlling mechanism 112—*a* which is manipulated by handle 112—*b*. Fluid for actuating rod 107 enters mechanism 112—*a* through conduit 112—*c*, and is exhausted from mechanism 112—*a* through conduit 112—*d*. To elevate the cylinder 110, fluid under pressure passes through mechanism 112—*a* and conduit 112, and exhaust fluid passes from cylinder 110 through conduit 112—*e* and mechanism 112—*a*. To lower the cylinder 110, handle 112—*b* is caused to function, and fluid under pressure passes through mechanism 112—*a* and conduit 112—*e*, and exhaust fluid passes from cylinder 110 through conduit 112 and mechanism 112—*a*. Rod 106 is actuated in a similar manner.

I show the screed 1 and associated parts elevated by means of the rods 106 and 107. Obviously the screed 1 may be tilted or sloped forwardly or rearwardly, or one end may be raised higher than the other, by suitable manipulation of the rods 106 and 107. Likewise, the screed 1 may be at an elevation below the tops of forms 2 through proper control of rods 106 and 107. I also show the pusher bar 102 hinged at end 115 to screed 1, and at end 116 to propelling machine, a part of which is indicated at 117. If instead of a hinge at 115, the pusher 102 be rigidly connected to screed 1, then rear wheels 101, rods 106 and cylinders 108 may be omitted, and the elevation of screed 1 may be controlled entirely by front rods 107, the whole apparatus swinging about hinge 118 on machine 117.

Pusher bar 102 may be omitted and propulsion of the screed 1 and associated apparatus may be accomplished by rotating wheels 101 or 101—*a* by any suitable means.

It is obvious that my method may be used with Portland cement concrete, bituminous concrete, or any other materials to which it is adapted.

It will be understood that any of the vibrating mechanisms herein described may be supported on a carriage such as here shown or on pavement or other machines, by vibration damping means such as are illustrated in my Patents No. 2,018,294, No. 2,094,910 and No. 2,110,413.

I claim:

1. The method of treating a material, the particles of which move relatively to each other when vibrated, consisting in simultaneously imparting to the material from a plurality of vibratory elements vibratory forces having components in at least three intersecting planes, thereby causing the particles to move relatively to each other.

2. The method of treating paving or like material, some particles of which best respond to vibratory forces of one frequency, and other particles of which best respond to vibratory forces of another frequency, by applying a plurality of frequencies of vibration to the material comprising bringing into contact with the material a body and subjecting the body to the action of a plurality of vibrators for simultaneously vibrating it with a plurality of frequencies and imparting such frequencies to the material, whereby some particles of the material are favorably affected by one frequency of vibration and other particles of the material are favorably affected by another frequency of vibration, thereby treating the material.

3. The method of treating a paving or like material, some particles of which best respond to vibratory forces of one frequency, and other particles of which best respond to vibratory forces of another frequency, the material also responding favorably to vibratory forces having components in a plurality of non-coincident planes, consisting in bringing into contact with the material a body and subjecting the body to the action of a plurality of vibrators for simultaneously vibrating it with a plurality of frequencies and imparting such frequencies to the material, and simultaneously imparting to the material vibratory forces having components in a plurality of non-coincident planes.

4. In an apparatus of the kind described, a member to be vibrated, a first shaft supported on the member, an out-of-balance weight on the first shaft, a second shaft supported on the member, an out-of-balance weight on the second shaft, a third shaft supported on the member, an out-of-balance weight on the third shaft, said shafts being so relatively located that their weights rotate in intersecting planes, means for rotating said shafts to thereby impart to the member vibratory forces having components in at least three non-coincident planes.

5. In an apparatus of the kind described, a member to be vibrated, a first weight supported on the member, power means rotating the first weight around a first axis of the member, a second weight supported on the member, and power means for oscillating the second weight along a second axis of the member intersecting the said plane, thereby imparting to the member vibratory forces having components in at least two intersecting planes.

6. In apparatus of the kind described, a member to be vibrated, a first weight supported on the member, power means rotating the first weight along a first axis of the member, a second weight supported on the member, power means for rotating the second weight around a second axis of the member non-coincident with the first axis, a third weight supported on the member, power means for rotating the third weight around a third axis of the member, thereby imparting to the member vibratory forces having components in at least three intesrsecting planes.

7. In an apparatus of the kind described, a member to be vibrated, a shaft supported on the member, an out-of-balance weight on the shaft, means for rotating the shaft, a reciprocating weight supported on the member, means for reciprocating the weight along an axis, the axis of the second weight intersecting the planes of rotation of the other weight, thereby imparting to the member, vibratory forces having components in a plurality of non-coincident planes.

8. In an apparatus of the kind described, a vibrating member adapted to be in contact with material to be vibrated, means for supporting the vibrating member, a plurality of vibratory means mounted on the member to vibrate in intersecting planes for imparting to the member vibratory forces having components in at least three non-coincident planes, for transmitting said vibratory forces to said material.

9. In an apparatus of the kind described, a support, a plurality of vibrating members mounted on the support and adapted to operate in contact with material to be vibrated, a vibrating means carried by each member for imparting thereto and therethrough to the material, vibratory forces said vibrating means being arranged in intersecting planes for creating vibratory forces having components in at least three intersecting planes.

10. In apparatus of the kind described, a carriage at least partly supported by wheels for engaging fixed means which restrain a material to be vibrated, means for propelling the carriage along said fixed means, a vibrating element mounted on the carriage and means for effecting upward and downward adjustment of the element relative to the wheels, said element being mounted to make lateral contact with the material during at least part of the interval of propulsion of the carriage, means associated with said element arranged for partial support of a portion of the material and means for vibrating said last-named means.

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