United States Patent

[11] **3,577,897**

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[21] Appl. No. **774,983**
[22] Filed **Nov. 12, 1968**
[45] Patented **May 11, 1971**

[54] **SONIC METHOD AND APPARATUS FOR LAYING AND REPAIRING ASPHALT MATERIAL**
3 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **94/48**
[51] **Int. Cl.** **E01c 19/30**
[50] **Field of Search** 94/48, 45

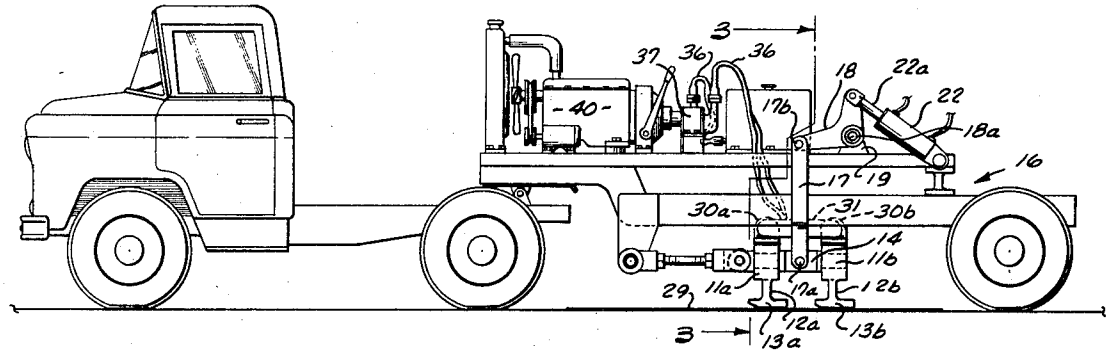
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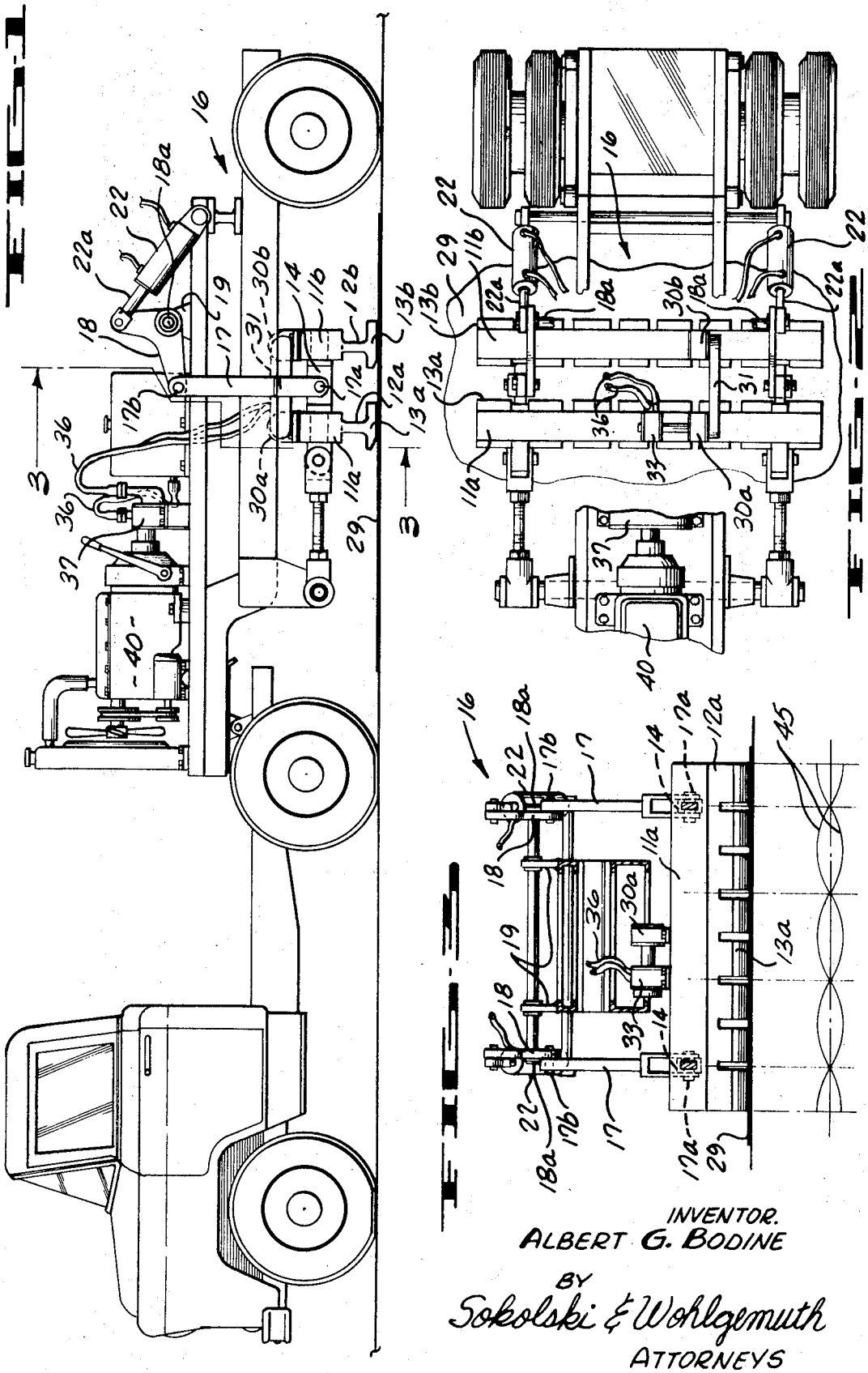
Primary Examiner—Jacob L. Nackenoff
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ABSTRACT: Sonic energy is generated by means of a self-contained resonant vibration system which utilizes an orbiting-mass oscillator as the sonic generator. The sonic energy is coupled from the resonant vibration system to a mixture of asphaltic material and gravel on a roadway structure or the like, this roadway material being excited as a resistive load. The resonant vibrational energy thus imparted to the roadway material causes random vibrations of the particles thereof which results in both a uniform mixing and a heating of the materials, as well as liquid migration therein, to provide a uniform asphalt concrete end structure.



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FIG. 4

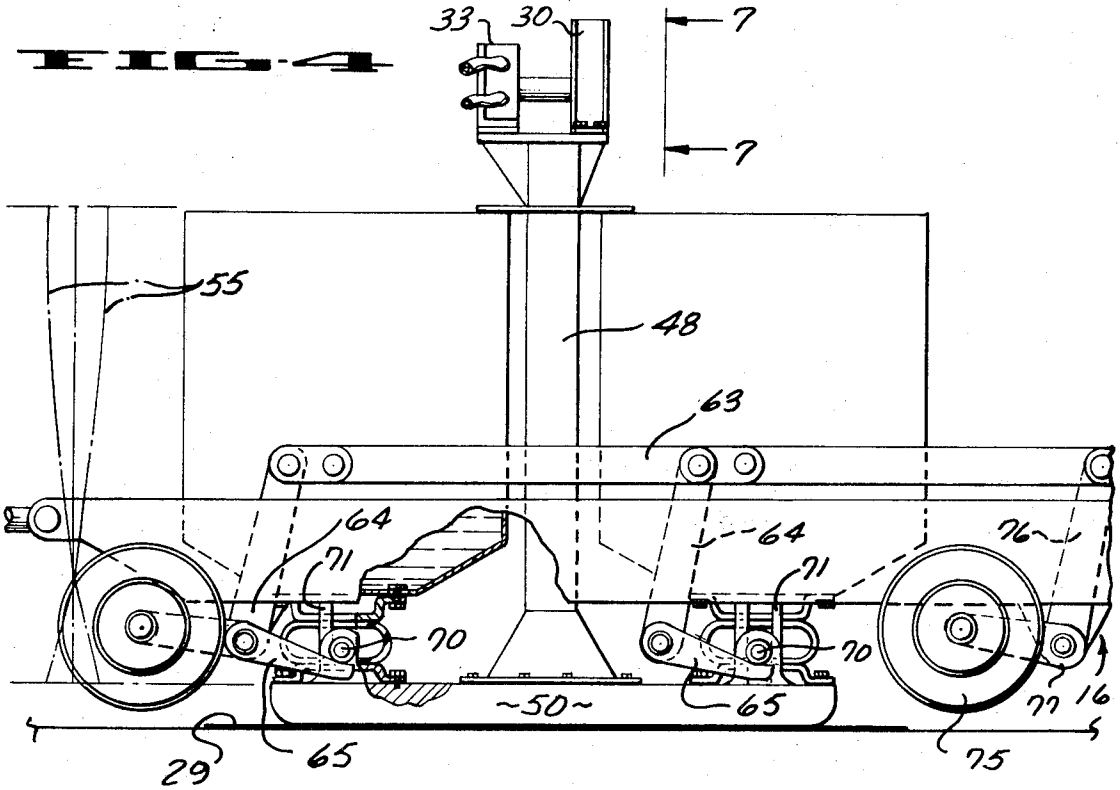


FIG. 5

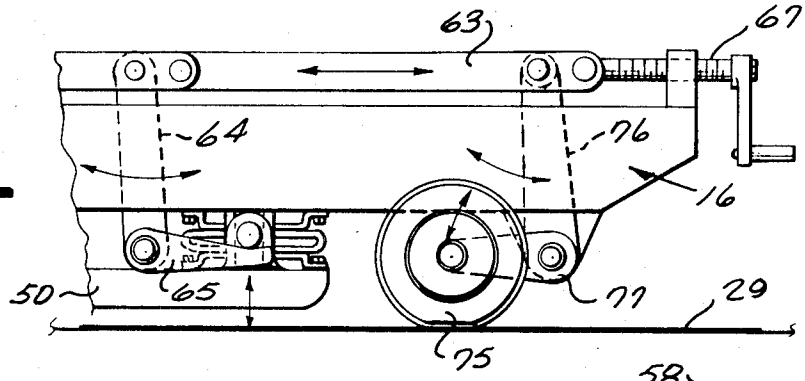


FIG. 6

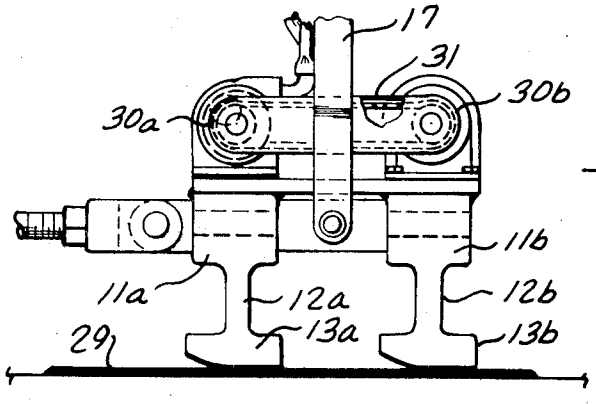
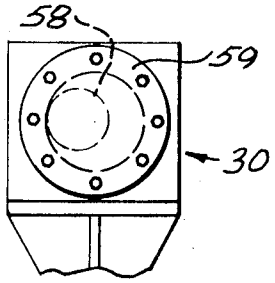


FIG. 7



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SONIC METHOD AND APPARATUS FOR LAYING AND REPAIRING ASPHALT MATERIAL

This invention relates to the laying and repair of asphaltic material and more particularly to the use of sonic resonant energy in such procedures.

In the laying of asphalt concrete structures, such as in the construction of roadways and the like, an asphaltic mixture of thick hydrocarbon liquid is combined with a gravel-type aggregate, with the asphaltic mixture being heated up to increase its fluidity during the mixing operation. This operation is usually performed at a bulk plant with the material being delivered to the site where it is to be used while still hot, where it is poured and compacted with a massive roller.

Asphalt concrete roadways tend to deteriorate due to the heating effect of the sum which causes the asphaltic material to drain down through the gravel, thus denuding the top gravel layers. To alleviate this problem, roadways of this type must be periodically sprayed with a thin oil to fill in the voids. To work effectively, the oil must be of a relatively low viscosity so that it will effectively seep into the interstices between the gravel. These repaired layers consequently tend to be of relatively low strength.

The technique and apparatus of this invention provides a significant improvement in both the laying of new asphalt concrete roadways and in the repair of same by utilizing sonic energy to implement these procedures. The technique and apparatus of this invention enables the construction of an asphalt concrete roadway by laying down granular material composed of aggregate and semisolid bituminous material without any requirement for preheating at a bulk plant, and carrying the heated material to the work site, the heating and thorough uniform mixing of the material being accomplished by means of sonic energy while the road is being laid. The sonic heating of the technique of this invention has the advantage over top heating of the prior art in that the heating of this invention results by virtue of the mechanical hysteresis of the material and thus is uniform throughout the mass, as contrasted with the nonuniformity of top heating wherein difficulty is experienced in getting heat to the bottom layers due to the poor heat-conduction characteristics of asphalt.

In the repair of existing roadways, the technique of this invention enables the utilization of fresh asphaltic material of high viscosity in filling in the deteriorated portions of the roadway, this end result being made possible by virtue of the combined heating and intermixing effect engendered by means of applicant's resonant vibration system. A particular advantage of applicant's technique is attained by virtue of the migration of the particles of asphaltic material engendered by the sonic energy, thus assuring thorough penetration of the original road material by the newly added material. The new material thus is made to efficiently fill the interstices in the deteriorated roadway structure. It is further to be noted that in certain instances it is possible to repair an old surface without adding new material by virtue of the mechanical hysteresis heating effect resulting from the sonic vibrational energy which brings the original material into a plastic condition so that it can readily be smoothed out and reformed as necessary.

It is to be noted at this point that applicant's system is to be distinguished from systems utilizing vibratory rollers which bodily vibrate the material being worked. Such systems fail to obtain random and relative vibration of the material as in applicant's technique where the material is made to act as a load on a self-contained resonant vibration system.

It is therefore the principal object of this invention to provide means for utilizing resonant sonic energy in the laying of asphalt concrete structures and in the repair of such structures.

The technique and apparatus of this invention will now be described in connection with the accompanying drawings, of which:

FIG. 1 is an elevational view illustrating a first embodiment of the device of the invention,

FIG. 2 is a top plan view particularly illustrating the sonic oscillator and resonant vibration system of the embodiment of FIG. 1,

FIG. 3 is a view taken along the plane indicated by 3–3 in FIG. 1,

FIG. 4 is an elevational view illustrating a second embodiment of the device of the invention,

FIG. 5 is an elevational view illustrating the vibrational plate member of the embodiment of FIG. 4 in its raised condition,

FIG. 6 is an elevational view illustrating the oscillator and the resonant vibration members of the embodiment of FIG. 1, and

FIG. 7 is a view taken along the plane indicated by 7–7 in FIG. 4.

It has been found most helpful in analyzing the technique of this invention to analogize the acoustically vibrating circuit utilized to an equivalent electrical circuit. This sort of approach to analysis is well known to those skilled in the art and described, for example, in Chapter 2 of "Sonics" by Hueter and Bolt, published in 1955 by John Wiley and Sons. In making such an analogy, force F is equated with electrical voltage E, velocity of vibration u is equated with electrical current i, mechanical compliance c_m is equated with electrical capacitance c_e, mass M is equated with electrical inductance L, mechanical resistance (friction) R_m is equated with electrical resistance R and mechanical impedance z_m is equated with electrical impedance z_e.

Thus, it can be shown that if a member is elastically vibrated by means of an acoustical sinusoidal force $F_0 \sin \omega t$ (ω being equal to 2π times the frequency of vibration), that

$$Z_m = R_m + j\left(\omega M - \frac{1}{\omega C_m}\right) = \frac{F_0 \sin \omega t}{u} \qquad (1)$$

Where M is equal to $1/\omega$Cm, a resonant condition exists, and the effective mechanical impedance Z_m is equal to the mechanical resistance R_m, the reactive impedance components ωM and $1/\omega$Cm cancelling each other out. Under such a resonant condition, velocity of vibration u is at a maximum, power factor is unity, and energy is more efficiently delivered to a load which the resonant system may be coupled.

It is important to note the significance of the attainments of high acoustical Q in the resonant system being driven, to increase the efficiency of the vibration thereof and to provide a maximum amount of power. As for an equivalent electrical circuit, the Q of an acoustically vibrating circuit is defined as the sharpness of resonance thereof and is indicative of the ratio of the energy stored in each vibration cycle to the energy used in each such cycle. Q is mathematically equated to the ratio between ωM and R_m. Thus, the effective Q of the vibrating circuit can be maximized to make for highly efficient, high-amplitude vibration by minimizing the effect of friction in the circuit and/or maximizing the effect of mass in such circuit.

In considering the significance of the parameters described in connection with equation (1), it should be kept in mind that the total effective resistance, mass, and compliance in the acoustically vibrating circuit are represented in the equation and that these parameters may be distributed throughout the system rather than being lumped in any one component or portion thereof.

It is also to be noted that orbiting-mass oscillators are utilized in the implementation of the invention that automatically adjust their output frequency and phase to maintain resonance with changes in the characteristics of the load as the equipment is moved along the roadway. Thus, in the face of changes in the effective mass and compliance presented by the load with changes in the characteristics of the work material as it is sonically excited, the system automatically is maintained in optimum resonant operation by virtue of the lock-in characteristic of applicant's unique orbiting-mass oscillators. Furthermore, in this connection the orbiting-mass oscillator automatically changes not only its frequency but its phase

angle and therefore its power factor with changes in the resistive impedance load presented by the asphaltic mixture, to assure optimum efficiency of operation at all times. The vibrational output from such orbiting-mass oscillators also tends to be constrained by the resonator to be generated along a controlled predetermined coherent path to provide maximum output along a desired axis.

Briefly described, the technique of this invention involves the application of sonic energy to an asphalt concrete material from a self-contained resonant vibration system. The sonic energy is generated by means of an orbiting mass oscillator which tends to automatically maintain resonant operation with changes in the characteristics of the load, the vibrational output of the oscillator in one embodiment of the device of the invention being coupled to resonant bar means which is placed in contact with asphaltic material to be initially laid or repaired, as the case may be. The resonant bar means is carried on a truck trailer and is supported on a hoist mechanism which can be operated to lift the bar means off the roadway and place it down thereon for successive operations, as desired.

Referring now to FIGS. 1—3 and 7, a first embodiment of the device of the invention is illustrated. Bar members **11***a* and **11***b* are joined by web structure **12***a* and **12***b* to plates **13***a* and **13***b* respectively. All of the aforementioned parts are made of an elastic material such as steel. Bar members **11***a* and **11***b* are joined together by connector bar **14** and are supported on truck bed **16** by means of arm member **17** which connects bar **14** to angle arm **18**. Arm member **17** is fixedly attached to bar **14** and arm **18** at points **17***a* and **17***b* respectively, while angle arm **18** is pivotally supported at point **18***a* on bracket **19** which is attached to the truck bed structure. Angle arm **18** is connected to the piston shaft **22***a* of cylinder **22** and may be driven about its pivot point **18***a* with the actuation of this cylinder. Thus, by the support and linkage mechanism described, plates **13***a* and **13***b* may be raised from and lowered onto road **29**, as desired.

Securely attached to the tops of bar members **11***a* and **11***b* are orbiting-mass oscillators **30***a* and **30***b*. These oscillators may be of the general type described in my U.S. Pat. No. 2,960,314 or as shown in FIG. 4 of my U.S. Pat. No. 3,406,782 and include a rotor which is mounted for eccentric rotation about a raceway formed in a housing, such eccentric or orbital rotation resulting in the generation of vibrational energy in the oscillator housing.

Oscillator **30***a* is rotatably driven by means of an hydraulic motor **33** which receives its hydraulic drive through line **36** running thereto from hydraulic pump **37**. The rotor of oscillator **30***a* is coupled to the rotor of oscillator **30***b* by means of chain drive **31**. Hydraulic pump **37** is in turn driven by means of gasoline engine **40**. An electrical drive motor may be utilized for driving oscillator **30***a* in lieu of hydraulic motor **33**, if so desired.

In operating the device of the invention, plate members **13***a* and **13***b* are lowered onto the asphalt concrete material on roadway **30** to be worked as shown in FIG. **1**, by means of cylinder **22**, and the speed of rotation of orbiting-mass oscillators **30***a* and **30***b* adjusted until resonant elastic vibration of the resonant vibration systems including members **11***a*—**13***a* and **11***b*—**13***b* respectively is achieved. Such resonant vibration of this system is evidenced by the appearance of standing waves along bar members **11***a* and **11***b*, as indicated in FIG. **3** by graph lines **45**, which is manifested by a peaking of the amplitude of vibration of the bar members as the speed of rotation of the rotors of the oscillator reaches the resonant condition.

The self-contained resonant vibration systems formed by members **11***a*—**13***a* and **11***b*—**13***b* are coupled to the asphalt concrete mixture which acts as a resistive load thereon whereby the individual particles of the load material are randomly vibrated relative to each other. This results in a thorough intermixing of such particles to form a uniform conglomerate. At the same time, the vibrational energy results in a mechanical hysteresis effect in the material which uniformly heats such material so that it tends to become a well integrated mass. As already noted, this can be used to equal effect both in laying new roadways from an aggregate formed of semisolid bituminous material and aggregate, and for repairing existing roadways either by providing filler material for filling in the deteriorated portions thereof or by smoothing out and effectively recombining the existing material. It is to be noted that the sonic energy provides maximum fluidity to the material being worked so that a rapid intimate mixing and penetration and wetting is accomplished all in one operation.

Referring now to FIGS. **4**, **5** and **7**, a second embodiment of the device of the invention is illustrated. In this second embodiment, the resonant vibration system is formed by longitudinal column **48** which is attached to flat plate member **50**, plate member **50** being utilized to couple the sonic energy to the asphalt concrete material on the roadbed **29**. Standing wave vibration of longitudinal column **48**, as indicated by graph lines **55**, is set up by means of orbiting-mass oscillator **30** which may be of the same type as described in connection with the first embodiment, including a roller **58** which is rotatably driven around a raceway formed in oscillator housing **59**. The rotor of oscillator **30** may be rotatably driven by means of an hydraulic motor **33** which may be driven by a drive system as described in connection with the first embodiment.

In the second embodiment, plate member **50** may be raised and lowered by means of a first system including linkage arms **63**, **64** and **65**, which are attached to and actuated by a jack rod **67** which is threadably supported on tailer bed **16**. Plate member **50** is shown in its lowered position in FIG. **4** and in its raised position in FIG. **5**. As can be seen in the FIGS., linkage arms **64** are pivotally attached to linkage arms **63** but fixedly attached to linkage arms **65**. Thus, with threaded bar member **67** in the position indicated in FIG. **5**, arms **65** are driven upwardly against pins **70** which project from the support structure for plate **50** and drive the pins, which are slidably supported in brackets **71**, upwardly thereby lifting the plate off surface **29**. Brackets **71** are fixedly attached to trailer bed **16**. On the other hand, with bar member **67** in an extended position, as for the case illustrated in FIG. **4**, arms **65** are lowered to permit plate member **50** to lie on the surface of the road. Linkage arm **63** also simultaneously drives the wheels **75** of the trailer through linkage arms **76** and **77** so that such wheels are retracted when the plate **50** is lowered and brought into contact with the roadway when plate member **50** is raised.

The technique and apparatus of this invention thus provides highly effective means for the working of asphalt concrete structures, both in the initial installation and the repair of such structures, whereby the material is sonically energized from a resonant vibration system and has a resistive load thereon.

I claim:

1. A device for use in working asphaltic material and aggregate into an integral mass in forming a roadway or the like comprising:

a resonant vibration system including an elastic bar member and plate means attached to said bar member,

an orbiting mass oscillator coupled to said resonant vibration system,

means for driving said orbiting-mass oscillator at a frequency such as to cause resonant elastic vibration of said vibration system,

a vehicle, said resonant vibration system, said oscillator, and said means for driving said oscillator being supported on said vehicle, and

means for selectively lowering said plate means so that it is in intimate contact with the material on said roadway to be worked, or raising said plate means so that it is away from the roadway.

2. The device of claim **1** wherein are included a plurality of bar members, an orbiting-mass oscillator supported on each of said bar members, said plate means comprising a plate member supported on each of said bar members.

3. The device of claim **1** wherein said bar member comprises a longitudinal column, said oscillator being supported on one end of said column, said plate means comprising a flat plate member attached to the other end of said column.