Title: IMPROVEMENTS IN OR RELATING TO THE REPAIR OF BITUMINOUS WEARING COURSES

Abstract: A method of repairing a damaged area of a bituminous wearing course including heating the damaged area with an infrared heater, raking the heated damaged area, applying a bitumen rejuvenating liquid composition to the raked heated damaged area, adding new material to the rejuvenated raked heated damaged area, compacting the new material to provide a compacted repaired area of bituminous wearing course, wherein said new material is applied cold and is in the form of a composition including aggregate, bituminous material and a naturally occurring mineral asphalt based liquid material. A composition for use as the new material in the method of repairing a damaged area of a bituminous wearing course includes aggregate, bituminous material and a naturally occurring mineral asphalt based liquid material, and is in a cold state. The damaged area may be heated by an infrared heater, said infrared heater comprising at least one radiator for applying heat to an underlying damaged bituminous wearing course, and control means for controlling the applied heat such that the heating temperature is defined by a lower predetermined limit and an upper predetermined limit.
INPROVEMENTS IN OR RELATING TO THE REPAIR OF BITUMINOUS WEARING COURSES

This invention relates to the repair of wearing courses or thoroughfares, such as roads, aircraft runways, car parks, sidewalks, railway station platforms or driveways and pavements made of a bituminous material such as asphalt or tarmacadam.

Bituminous wearing courses such as asphalt are generally composed of about 94% aggregate (stone chips, gravel, or sand) and about 6% bitumen binder. The bitumen binder is composed of hydrocarbons and has ionic properties, which serve to bind the sand and gravel particles together. It is compounds, broadly speaking called maltenes, that give the bitumen its ionic properties of binding and flexibility and that are lost through oxidation. Such wearing courses deteriorate through oxidation of the bituminous binder. The oxidation process reduces the ionic properties of the bitumen, which in turn leads to release of the aggregate. The oxidised binder loses its flexibility and the surface shrinks and cracks. The effects of traffic and weather (temperature changes and moisture) speed up this process. After general release of the aggregate, larger flaws appear which eventually turn into potholes. Furthermore, the oxidation process accelerates other damage to the wearing course and failure of joints and seams especially from conventional repairs around ironwork surrounding manholes, and trenchwork.

The repair of pot holes in most roads and pavements in the UK is under the direction of the local county councils who regularly inspect the roads and pavements for damage and also have a ‘reactive’ service where they aim to repair temporarily a pot hole within 24 hours of it being reported. The temporary repair of the potholes involves filling the pot hole with cold set materials (known as ‘cut back’ materials) which are compressed into the hole. The temporary repair material must normally be replaced with a permanent repair material within a few months of the temporary repair. Although the temporary repairs reduce hold-ups for road users and return the road to an acceptable safety level quickly, they often require replacement a number of times pending permanent repairs, especially during very wet weather conditions.
A system and a composition for permanently repairing bituminous wearing courses, in particular where areas of the wearing courses have been damaged for example by the formation of cracks, fissures, potholes, trenches, failed joints and failed seams, is disclosed in the specifications of the Applicant’s UK Patent Nos. 2,345,714 and 2,352,750 (the subject matter of which is incorporated into this specification by reference). The disclosed repair involves the damaged areas being heated with a fibre blanket infrared heater, then being raked so as to mix highly oxidised top surface material of the damaged area with less oxidised sub-strata. A temperature resistant bitumen rejuvenating liquid composition is then applied to the raked heated damaged area. New material, for example aggregate or bituminous material such as asphalt or hot rolled asphalt, is added to the rejuvenated raked heated damaged area and the new material is compacted to provide a compacted repaired area of bituminous wearing course.

The bitumen rejuvenating liquid added to the damaged area generally comprises compounds that have been lost from the bitumen in the damaged area, i.e. the maltenes mentioned previously which are generally rich in polar compounds. The replacement of the lost polar compounds restores that ability of the bitumen to bind the aggregates such as stone, gravel or sand in the wearing course surface. The maltenes and other lost compounds, that give the bitumen its ionic properties of binding and flexibility, in the bitumen rejuvenating liquid enables the damaged bitumen to be recycled, avoiding having to dig out and replace dug out material with new material within the area being repaired. Thus, the application of the bitumen rejuvenating liquid to the damaged area restores the bitumen to its original state.

Fibre blanket infra-red heaters are known from US Patent Nos. 4,749,303 and 5,114,284 in which the heater has two folding sections with castors at the four corners to allow manual positioning over desired areas of pavement. A blower is run continuously to supply constant pressure air to an air channel and the flow of propane fuel into the continuous air stream produced by the blower is regulated by manually operated control valves located in a control panel to produce a combustible mixture. The air and fuel are fed separately to a respective mixing channel (chamber). Each folding section of the heater has an outer shell forming an open bottomed frame constituting a manifold (compartment) of which the bottom wall is formed by refractory ceramic fibre blanket which also forms the roof of a heating chamber.
with an encircling skirt. Fuel/air combustible mixture delivered from the mixing channel is able to slow down and evenly distribute its pressure throughout the manifold and is forced down through micro spaces between the fibres in the refractory ceramic fibre blanket to be burned across its lower surface, radiating heat downward.

Another fibre blanket infrared heater developed, and used by the Applicant in carrying out the system disclosed in the above mentioned UK patents comprises a closed frame containing a downwardly-directed radiant heating surface consisting of a mineral wool blanket and at least four slidably mounted supporting legs bearing castor mounted wheels to adjust the height of the heater from the wearing course surface. The closed frame is split into four (in the largest) separate heating panels each comprising an enclosed compartment of which the lowest face is presented by the mineral wool blanket and into each of which flammable (propane) gas and air are separately introduced, with the gas being burnt on the radiant heating surface of the blanket. The gas is supplied through a pressure control valve to a solenoid valve which in turn controls flow to a manifold from which four separate valves control the individual supply of gas to each of the four panels through flexible supply pipes. The solenoid valve is opened and closed in response to control signals from a timer control which switches the flow of gas on and off according to a pre-set cycle which can be varied to increase or decrease the operating temperature of the panels by a manual control. The manual control varies the relative lengths of the on and off periods within a predetermined range, so that the length of time of the off period is always sufficiently short to ensure that when the gas flow is restored ignition occurs at the external face of the mineral wool blanket. Thus, the gas flow control automatically switches the gas flow on and off according to a predetermined cycle of off and on time periods, the cycle being manually chosen from a selection of predetermined cycles. Air from a blower/fan passes to a manifold supplying air to the heating panels by separate pipes, with the gas passing through a separate connection. The gas and air are mixed in respective inlet chambers from whence the gas/air mixture passes to the compartments of the separate heating panels through respective metal gauze flame arresters that ensure safety by avoiding explosions if the gas/air mixture ignites in the compartments. A sensor is used to detect when the correct temperature has been reached or a sudden rise in temperature within the heating panels and to send a signal to the gas supply and switch off the flow of gas. Asphalt temperature detectors signal the gas supply to stop gas flow if the temperature approaches the level at which charring can occur.
Both these prior art infrared heaters suffer from the disadvantage of using a blower which provides, with the supply of propane gas, a gas/air mixture which is mixed in respective inlet chambers and regulated, e.g. by control valves, to produce a flammable mixture and which provides sufficient pressure to force the gas through the micro spaces between the fibres in the fibre blanket. However, the disadvantage of using a gas/air mixture is the risk of explosions if it ignites in the compartments. Whilst flame arresters can be used with a view to ensuring that such explosions cannot occur, such safety measures have been found not always to be failsafe. Also, the blower requires a supply of compressed air either from a compressor or compressed air cylinders, which is an additional expense.

Although the system of permanently repairing bituminous wearing courses described above is a successful method of permanent repair, it is not appropriate for the rapid repair of potholes i.e. within 24 hours of the potholes being reported. In practice, the existing system which is disclosed in the aforementioned UK patent specifications requires the new material which is supplied from the manufacturer in a hot condition to be kept hot until it is placed onto the heated rejuvenated damaged area. This is because, once cooled, the new material cannot be reconstituted and so will be ineffective. Therefore, existing practical systems also include a hot box for storing the hot new material and transporting the hot new material to the damaged area. The hot box is usually in the form of an extra vehicle, making the system quite clumsy, and must be pre-heated to ensure that the new material stays hot. It is for these reasons that the existing system is more suited to, and particularly efficient at, repairing relatively large areas of damaged wearing courses.

Objects of the present invention are to provide an improved system of repairing bituminous wearing courses including a method, a composition for the new material added to the rejuvenated raked heated damaged area and an infra-red heater for use in the method.

From one aspect the present invention resides in a method of repairing a damaged area of a bituminous wearing course including heating the damaged area with an infrared heater, raking the heated damaged area so as to mix highly oxidised top surface material of the damaged area with less oxidised sub-strata, applying a bitumen rejuvenating liquid composition to the raked heated damaged area, adding new material to the rejuvenated raked
heated damaged area, and compacting the new material to provide a compacted repaired area of bituminous wearing course, characterised in that said new material is applied cold and is in the form of a composition including aggregate, bituminous material and a naturally occurring mineral asphalt based liquid material.

Advantageously, as the new material is applied cold, there is no need for a hot box or other device to heat or keep the material warm. This means that the method is both less clumsy and more rapid than existing repair methods.

Preferably, before compacting the new material, the method further includes raking the cold new material to ensure mixing of the new material with the bitumen rejuvenating liquid composition and the material of the damaged area.

To provide a further boost of bitumen rejuvenating compounds into the surface of the compacted repaired area and binding and sealing the surface of the compacted repaired area, a topcoating liquid is applied consisting essentially of gilsonite, asphalt cement, solvent and antistripping agent to the surface of the compacted repaired area.

From another aspect, the present invention resides in a composition for use as a new material in a method of repairing a damaged area of a bituminous wearing course, said new material composition being in a cold state and including aggregate, bituminous material and a naturally occurring mineral asphalt based liquid material.

Preferably, the aggregate comprises 92.4% by weight of the new material, the bituminous material comprises 2% by weight of the new material, and the naturally occurring mineral asphalt based liquid material comprises 5.6% by weight of the new material. The aggregate blend comprises stone and sand, the stone comprising 68.2% of the aggregate blend and the sand comprising 31.8% of the aggregate blend.

By means of the method and composition of the invention the disadvantages of using hot new material and what used to be a temporary pothole repair needing a replacement to provide a permanent repair are overcome or at least substantially reduced.
Practically, the naturally occurring mineral asphalt of choice is Gilsonite which is 99% pure and which has exceptional binding and adhering qualities, i.e. Gilsonite based liquid material.

In a preferred embodiment of the invention, the Gilsonite based liquid material consists essentially of Gilsonite, asphalt cement, solvent and anti-stripping agent.

The Gilsonite and asphalt cement may be 20 to 60 parts by weight of the Gilsonite based liquid material, the solvent may be 20 to 80 parts by weight of the Gilsonite based liquid material and the anti-stripping agent may be 1 to 5 parts by weight of the Gilsonite based liquid material. The solvent of the Gilsonite based liquid material may comprise petroleum kerosene/naphtha, VM&P naphtha and/or lactol spirits.

A particularly preferred Gilsonite based liquid material which is naphtha based is sold under the trade name GSB-78 and has the following composition:

<table>
<thead>
<tr>
<th>Product</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gilsonite and</td>
<td>CAS Registry #12002-43-6 35-45%</td>
</tr>
<tr>
<td>Asphalt Cement</td>
<td>CAS Registry#8052-42-4</td>
</tr>
<tr>
<td>Solvents</td>
<td>50-60%</td>
</tr>
<tr>
<td>Petroleum Kerosene/Naptha</td>
<td>CAS Registry #8008-20-6</td>
</tr>
<tr>
<td></td>
<td>CAS Registry #64741-41-9</td>
</tr>
<tr>
<td>VM&amp;P Naptha</td>
<td>CAS Registry #8032-32-4</td>
</tr>
<tr>
<td>Lactol Spirits</td>
<td>CAS Registry #64742-89-8</td>
</tr>
<tr>
<td>Anti-stripping agent</td>
<td>up to 5%</td>
</tr>
</tbody>
</table>

CAS - Chemical Abstract Service

In order to produce GSB-78, the components are put together in a blend tank and agitated until homogenous and the Gilsonite has dissolved.

Preferably, the cold new material composition is a mixture of aggregate blend (63% stone, normally high PSV stone in the form of chippings or gravel, and 29.4% sand), 2% bitumen, and 5.6% Gilsonite based liquid material, in particular GSB-78. Expressed another way, a 25
kg mix of the new material would be 15.75 kg stone, 7.35 kg sand, 0.5 kg bitumen and 1.4 kg Gilsonite based liquid material, in particular GSB-78. Although 63% stone content is preferred, the content of the stone can vary according to the application and according to BS 594 Part 1. Conveniently, the stone and sand aggregate are coated with bitumen in a standard hot mix plant which involves heating and mixing together the stone, sand and bitumen. The mixture is discharged from the plant and left to cool. The Gilsonite based liquid material, in particular GSB-78 is added to the cooled mixture and mixed in a bell mixer for at least thirty seconds to ensure coating. The bitumen and the Gilsonite based liquid material, in particular GSB-78, content in the new material composition can vary slightly but the Applicants have found that a bitumen content of more than 2.5% does not work in that the aggregate sets solidly when cooled and is no longer workable. Further, the Applicants have also found that a Gilsonite based liquid material, in particular GSB78, content of more than 5.6% results in the Gilsonite based liquid material, in particular GSB-78, segregating from the rest of the mix. Therefore, the preferred content of the bitumen is less than 2.5% and the preferred content of the Gilsonite based liquid material, in particular GSB-78, is 5.6% or less.

Surprisingly, the applicants have found that the addition of Gilsonite based liquid material, in particular GSB-78, to the mixture of stone, sand and bitumen enhances the durability of the new material in that it improves its resistance to oxidation.

The cold new material composition added is only that which is required to level the repaired pothole with some small surplus, i.e. substantially the amount of material that has been worn out of the surface. The new material composition is generally raked level and then compacted, e.g. by rolling as with a vibrating roller. At this stage the compacted surface, once it has cooled, is capable of accepting traffic. The new material may also assist in knitting of the joint between the new material and the existing wearing course.

Depending upon the composition of the damaged bituminous wearing course being repaired, the bitumen rejuvenating liquid composition should be resistant to breakdown at least up to 200°C and may be resistant to breakdown at temperatures of up to 500°C.
The bitumen rejuvenating liquid composition is conveniently sprayed onto and worked thoroughly into the mix to ensure complete coating of the heated material and preferably, consists essentially of a cationic slow set emulsifier, a heavy paraffinic distillate solvent extract, a heavy naphthenic distillate solvent extract and water. Alternatively, the bitumen rejuvenating liquid composition consists essentially of a cationic slow set emulsifier, a heavy paraffinic distillate solvent extract, a heavy naphthenic distillate solvent extract, a naturally occurring mineral asphalt such as Gilsonite and water.

The bitumen rejuvenating liquid preferably contains from 30 to 80 parts by weight in total of the heavy paraffinic distillate solvent extract and the heavy naphthenic distillate solvent extract, from 10 to 60 parts by weight of water, and from 1 to 5 parts by weight of the emulsifier. More preferably, the liquid comprises from 60 to 65 parts by weight in total of the heavy paraffinic distillate solvent extract and the heavy naphthenic distillate solvent extract, from 30 to 35 parts by weight of water and from 1 to 5 parts by weight of the emulsifier.

A particularly preferred rejuvenating liquid is one that we have named “GSB-99” and which has the following composition:

<table>
<thead>
<tr>
<th>Product</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aromatic Oil Solvent Extract</td>
<td>60-65%</td>
</tr>
<tr>
<td>Heavy Paraffinic Distillate Solvent Extract</td>
<td>CAS Registry #64742-04-7</td>
</tr>
<tr>
<td>Heavy Naphthenic Distillate Solvent Extract</td>
<td>CAS Registry #64742-11-6</td>
</tr>
<tr>
<td>Water (H₂O)</td>
<td>30-35%</td>
</tr>
<tr>
<td>Emulsifier</td>
<td>up to 5%</td>
</tr>
</tbody>
</table>

CAS = Chemical Abstract Service

In order to provide a further boost of bitumen rejuvenating compounds into the surface of the compacted repaired area and bind and seal the surface of the compacted repaired area, a topcoating liquid consisting essentially of a naturally occurring mineral asphalt such as Gilsonite, asphalt cement, solvent and anti-stripping agent (cohesion agent) is applied with standard bituminous distributors and/or hand spraying to the surface of the compacted repaired area. Preferably, the Gilsonite and asphalt cement are 20 to 60 parts by weight of the
topcoating liquid, the solvent is 20 to 80 parts by weight of the topcoating liquid and the anti-stripping agent is 1 to 5 parts by weight of the topcoating liquid. The solvent may comprise petroleum kerosene/naphtha, VM&P naphtha and/or lactol spirits. In practice, the top coating liquid used is the Gilsonite based liquid material referred to above as GSB-78.

Finally, a dusting of fine aggregate (e.g. aluminium silicate) or that fine aggregate marketed under the trade mark Black Rhino™ may be added to ensure good initial skid resistance.

From a further aspect, the present invention resides in an infrared heater for use in repairing a damaged bituminous wearing course, said infrared heater comprising at least one radiator for applying heat to an underlying damaged bituminous wearing course, and control means for controlling the applied heat such that the heating temperature is defined by a lower predetermined limit and an upper predetermined limit.

Advantageously, the control means is operative to supply flammable gas to the at least one radiator by automatically switching on the flow of gas until the upper temperature limit is reached, when the upper temperature limit is reached automatically switching off the flow of gas, and when the lower temperature limit is reached automatically switching on the flow of gas again, whereby to apply a pulse of heat to the underlying damaged bituminous wearing course.

In a preferred embodiment, the lower predetermined limit is defined by a predetermined temperature drop relative to the upper predetermined temperature limit.

The infrared heater further comprises a heat sensor arranged to sense the temperature of the heat being applied to the underlying damaged bituminous wearing course. Advantageously, the control means is operative to compare the sensed temperature of the heat being applied to the underlying damaged bituminous wearing course with the said predetermined temperature limits and automatically to switch the flow of gas on or off according to the predetermined temperature limits.

By means of this aspect of the invention, the heat applied to the damaged bituminous wearing course is pulsed between the two predetermined temperature limits regardless of the ambient
temperature and weather conditions. This enables effective heating of the damaged bituminous wearing course without charring or burning the damaged bitumen.

In a preferred embodiment, the infrared heater further comprises a timer automatically to switch the flow of gas off after a predetermined time interval. By this means, the timer can be set to automatically turn off the flow of gas, and hence the heat being applied to the damaged bituminous wearing course, after a predetermined time interval which may include, for example, 10 pulses of heat to the underlying damaged bituminous wearing course, or part of a pulse.

Preferably, the at least one radiator comprises a housing defining a gas receiving chamber which is closed by a mesh cover, and a diffuser having a mesh surface in the chamber on which surface the gas ignites to heat the damaged bituminous wearing course.

In a preferred embodiment, the infrared heater comprises a multiplicity of said at least one radiators arranged in the form of an array.

Inventive aspects avoid the risk of explosions because an air blower is not present as well as the use of a compressor or compressed air supply cylinders, thereby reducing costs. Moreover, the use of an electronically controlled timing and heating system improves heating efficiency by being far more sensitive to the heating parameters, wearing course properties and the prevailing conditions.

In order that the invention may be more readily understood, reference will now be made to the accompanying drawings in which:-

Figure 1 is a side elevation of an infrared heater used in the system of repairing a damaged bituminous wearing course according to the invention;

Figure 2 is an end elevation of the infrared heater of Figure 1;

Figure 3 is a top plan view of the infrared heater of Figure 1;
Figure 4 is an enlarged detail view of the encircled portion of Figure 2 showing a height adjustment upright forming part of the infrared heater of Figure 1;

Figure 4a is a detail top plan view of a gas infrared radiator supply conduit to four infrared radiators forming part of the infrared heater of Figure 1;

Figure 4b is a schematic drawings of the gas infrared radiator supply conduit and two of the four infrared radiators, shown in cross-section, of Figure 4a;

Figure 5 is a schematic drawing of a control panel on the front face of an electronic control box forming part of the infrared heater of Figure 1;

Figure 6 is a schematic drawing of components accommodated in a pilot burner box with its cover plate removed and forming part of the infrared heater of Figure 1;

Figure 7 is a schematic drawing of a side face of the electronic control box forming part of the infrared heater of Figure 1;

Figure 8 is a schematic drawing of the electronic control box forming part of the infrared heater of Figure 1 viewed from the opposite side to that shown in Figure 7;

Figure 9 is a block circuit diagram showing the relationship of the key components of the infrared heater of Figure 1;

Figure 10 is a large-scale version of the infrared heater of Figure 1 which operates in the same way;

Figures 11 and 12 are side views of the infrared heater of Figure 10 showing the minimum and maximum heights of gas infrared radiators forming part of infrared heater of Figure 10 from the road surface and which are equally applicable to the infrared heater of Figure 1;
Figure 13 is a detail side view showing two infrared radiators (burners) forming part of the infrared heater of Figure 10 and which are the same as those of the infrared heater of Figure 1;

Figure 14 is an enlarged detail view of the encircled portion of Figure 14;

Figures 15 and 16 are top plan views of the infrared heater of Figure 10, without and with perforated safety plates and the electronic control box forming part of the infrared heater of Figure 10 and which are also used in the infrared heater of Figure 1;

Figure 17 is a side elevation of an alternative embodiment of the infrared heater of Figure 1;

Figure 18 is an end elevation of the infrared heater of Figure 17;

Figure 19 is a top plan view of the infrared heater of Figure 17;

Figure 20 is a side elevation of an alternative infrared heater of the infrared heater of Figure 10;

Figure 21 is an end elevation of the infrared heater of Figure 20;

Figure 22 is a top plan view of the infrared heater of Figure 21; and

Figure 23 is a schematic drawing of an alternative embodiment of the control panel of Figure 5.

Referring initially to Figures 1 to 16 of the drawings, an infrared heater for heating a damaged bituminous bound surface A (Figures 1, 2, 11 and 12) of a wearing course B (Figures 11 and 12) is generally indicated by the reference 10 and comprises a galvanised rectangularly shaped steel main frame 12 on which all other components of the infrared heater 10 are supported and retained. The infrared heater of Figures 1 to 8 is of lightweight construction as compared to that of Figures 10 to 16 and is adapted for use in speedily
repairing small damaged areas, in particular potholes to which end the heater is provided with a lifting means to be described. The lightweight infrared heater is of rectangular shape and in this embodiment is generally square-shaped. On the other hand, the larger infrared heater 10 of Figures 10 to 16 is for particular use on larger damaged areas although it can also be used in the repair of smaller damaged areas, if desired or necessary. In this regard, the larger infrared heater comprises two units removably joined together. By this means, the two units can be separated from each other (by effectively splitting the larger infrared heater into two along its length) and used end-to-end for trench, or other narrow, repairs. A bolting device is provided on the larger infrared heater 10 to hold the two units of the heater 10 together. The bolting device includes handles 11 (Figure 10) to assist in separating the two halves of the heater. The two units are substantially the same, therefore, for ease of understanding, the following description refers only to a single unit of the larger heater 10.

Suspended below, and supported from, the main frame 12 are banks of stainless steel gas infrared radiators 13 arranged in rows extending lengthwise of the infrared heater 10. The main frame 12 constitutes a chassis 12 carrying four wheels 14 with solid tyres at its four corners respectively and supported from the lower ends of substantially vertically adjustable uprights 16 which are slidable in sleeves 18 fixed to laterally extending substantially horizontal arms 20 that are pivotably mounted on the frame 12. The uprights 16 and sleeves 18 are provided with a series of substantially vertically located registrable holes 22 which can be engaged by pins (not shown) to fix the uprights and thus the height of the gas infrared radiators 13 from the surface A of the damaged wearing course B to be heated. The uprights 16 are adjustable between the minimum height position shown in Figures 11, 13 and 14 where the radiators 13 are closest to the surface A and a maximum height position, shown in Figure 12, where the radiators 13 are furthest away from the surface A. Each of the front two wheels is fitted with a respective brake (not visible) and all the wheels 14 can be swivelled horizontally through the range of movement indicated in dashed lines in Figure 3 by pivoting its associated arm 20.

A wind breaker skirt 15 is removably mounted to the underside of the main frame 12 and surrounds the gas infrared radiators 13 (Figures 10 to 14). The wind breaker skirt 15 occupies a position close to the surface A in Figure 11 in order to reduce to a minimum any adverse
affects on the heating temperature due to wind, rain or any other prevailing weather conditions.

Referring more specifically to Figures 4a, 4b and 14, each gas infrared radiator 13 comprises a housing 13a defining a gas receiving chamber in which the gas/air mixture can circulate and which is closed by a mesh cover in the form of a grid 13b, with there being a gas diffuser 13c inside the chamber of the housing 13a and extending towards the grid 13b. The diffuser has a mesh surface 13d on which the gas/air mixture ignites to heat the wearing course surface. The grid 13b forms a curved radiating surface onto which the ignited gas/air mixture is directed downwards by the diffuser 13c. The applicant has found that the diffuser 13c also acts as a flame arrester so that the gas/air mixture does not ignite upstream of the diffuser. The distance in height between the curved downwardly facing surface of the radiator grids 13b to the road surface is adjustable from 6 cm to 10 cm by releasing uprights 16 with respect to the sleeves 18 and sliding them in the appropriate direction in the sleeves 18.

Rigidly mounted, as by welding, to the upper surface of the main frame 12 are two sub-frames 24 providing handles 26 for manoeuvring the infrared heater 10 when free standing on its four wheels 14, as shown. The lightweight infrared heater, as can be seen in Figures 1 to 3, is provided with a lifting means 28 having a lifting bar 30 and chains 32 secured to respective brackets 33 rigidly fixed to the sub-frames 24 for use in lifting and lowering the infrared heater 10 in a manner to be described. Tubes (not shown) can be fitted to the sub-frames 24 to enable the heater to be mounted onto a vehicle (not shown) used to transport the heater 10 from one working site to another by means of a framework arrangement.

Using an appropriate hoisting apparatus comprising hydraulic rams and/or a pulley system situated on the bed of a truck (not shown) and connected to the lifting means 28, enables the lowering and positioning of the infrared heater 10 over the defective area A to be remotely controlled in vertical and transverse planes. On completion of a heating cycle the infrared heater 10 can then be raised by the hydraulic rams and/or a pulley system into its transportation position on the vehicle. The infrared heater 10 can be removed from this frame if so desired and operated free standing, as illustrated, using its wheels 14 for positioning.
The larger infrared heater 10 does not have a lifting bar and chains and is lowered and positioned over the defective area by means of a lowering platform on a vehicle (not shown). The lightweight heater can also be lowered and positioned in a similar fashion.

Propane gas is fed to the infrared gas radiators 13 as controlled by a gas management system (to be described) through conduits from two 19 kg cylinders (not shown) which are placed on the two perforated metal trays 17 fixed to the main frame 12. The gas cylinders have respective on/off valves and can be maintained in position with the aid of a fixing frame 19 (Figures 2, 10, 11, and 12) where they are connected via a ball valve (not shown) to gas supply conduits to be described. In the larger infrared heaters of Figures 10 to 16, these perforated metal trays 17 act together with a perforated metal plate 17a (Figures 10, 11, 12 and 16) as protective safety covers for the gas infrared radiators 13.

The gas supply conduits include a series of spaced apart gas infrared radiator supply conduits 23 extending length-wise of the infrared heater 10. There are knuckle-shaped connector conduits 25 connecting the supply conduits 23 to the gas chambers of the individual gas infrared radiators 13. Each supply conduit 23 communicates with a respective elbow 23a terminating in an end portion 23c covered by a mesh housing 23b. The end portion 23c has at least one opening 23d (two are visible in Figure 4b) through which air can pass into the supply conduit 23. The end portion 23c also includes a nozzle 23e which is connectable to a header conduit 29 to which the gas cylinders can be connected via the ball valve at the fixing frame 19. In this way, gas is supplied to the supply conduits 23 via the nozzle 23e and mixes, in the supply conduits 23, with the air passing through the opening 23d such that the gas-air mixture enters the gas chambers in the radiator housings 13a where it ignites. The gas pressure is set by a variable regulator in the form of a pressure governor (not shown) and, which regulates the heating capacity and thus the heat output of the gas infrared radiators 13 when working on heat sensitive materials such as mastic asphalt.

A gas ignition system comprising at least one (two in this embodiment) pilot burner boxes 27 (to be described later) is installed at the rear of the main frame 12 as illustrated to provide the ignition source for the gas infrared radiators 13, and is provided with a thermal safety control system including thermocouple safety devices 31 (Figure 6).
As can more readily be seen from Figure 1, the right-hand, as illustrated, sub-frame 24 supports a control box 34 which has a control panel 35 (Figure 5) and which is positioned in, and rigidly mounted on, this sub frame. The control box 34 has a front face 34a (control panel 35), a side face 34b and a top face 34c. In order to supply power to the electronic gas management system by switching on a main on/off switch 36 on the front face 34a of the control box, a 12-volt car type battery 37 is mounted on the same right hand sub frame within the illustrated compartment. A voltmeter shows the status of the battery as to whether the battery has to be recharged or not via a visual display comprising three LEDs indicated at 38 on the control panel 35. The battery is recharged (normally weekly) with a 12 V charger supplied with the infrared heater 10 through a battery charging socket 39 (Figure 7). Alternatively, the battery can also be replaced rather than recharged, or removed and recharged, which renders the battery charging socket superfluous.

Full control of heat input and pulsed heating is facilitated by adjustments made in the control box 34. The control box 34 houses a variable timer having an external control knob 40 on the side face 34b (Figure 7) and having an on/off timer switch 41 on the control panel 35. The timer is set to govern the duration of the heating cycle by manually turning the control knob 40 to the appropriate position according to the bituminous material composition of the damaged wearing course being worked and the prevailing conditions. With the timer switch 41 switched on, turning of the control knob 40 to the selected position initiates commencement of the heating cycle by opening a solenoid valve 40a via an electrical lead 40b to supply gas to the infrared radiators 13 which are ignited to heat the surface A. A flashing green light 50 on the control box 34 (Figures 1, 8, 11 and 12) is connected to the timer when the timer switch 41 is switched on to indicate that the heating cycle has commenced by the opening of the solenoid valve 40a. At the same time, light 43 on the control panel 35 glows orange to provide a visual indication that the radiators 13 are ignited.

Also housed within the control box 34 is an electronic controller 47 (Figure 9) for setting the temperature to which the surface A will be heated on each timed cycle. The electronic temperature setting means involves the use of an infrared sensor (not visible) mounted on the under surface of the main frame 12 close to the surface A to send signals constantly corresponding to the temperature of the heated area to the electronic controller 47. The actual temperature resulting from the signals is displayed digitally on an LED screen 42 on the
control panel 35. The temperature settings are programmable through the buttons 42a on the control panel 35 and will be indicated on the LED screen 42.

When the temperature of the surface A reaches the pre-determined value, the gas delivery to the radiators 13 is interrupted by the electrical supply to the solenoid valve 40a being switched off causing the solenoid valve 40a to close, until the temperature drops by a predetermined amount relative to the maximum set value. This situation then repeats itself until the timer switches off the infrared heater 10 at the end of the cycle by cutting off the supply of propane gas to the radiators 13 via the solenoid valve 40a. The heating operation involves a series of frequent pulses of heat being applied to the bituminous bound surface A, giving an even penetration of heat to the required depth without charring.

The bringing into operation of the gas supply to the gas infrared radiators will now be described. With the main switch 36 in the off position, all the valves of the gas supply system are closed, including the gas cylinder valves and ball valve at the gas cylinder fixing 19 and the solenoid valve 40a. The following sequence of actions is then taken:-

1) both gas cylinder valves are opened;
2) the gas cylinder fixing ball valve is opened; and
3) the pressure governor is turned into the required position.

Referring more particularly to Figure 6, these actions cause gas to flow into two safety pilot burners 44 in the two pilot burner (pilot light) boxes 27 respectively. By lifting the cover plate of the pilot burner boxes 27 access can be obtained to each pilot burner 44 and a safety valve 46. By pressing a pressure pin 48 on the safety valve 46 and keeping the pin 48 pressed, gas will flow into the pilot burner 44. The gas flowing to the pilot burner 44 is then ignited following which the pressure pin 48 is kept pressed for 10 to 15 seconds. When the pilot burners 44 of both pilot burner boxes are ignited, the gas infrared radiators 13 are ready for operation. The flame from each pilot burner 44 is directed towards the nearest gas infrared radiator 13 by a flame deflector (not shown) which ensures that the gas/air mixture ignites at the gas diffuser 13d when the gas is flowing. A by-pass valve (not shown) operated by a control knob 52 is provided to by-pass the solenoid valve 40a in gas conduit 54 and allow the gas to flow through gas conduit 56. By this means, the infrared heater 10 can be manually operated when the electronic timing system has malfunctioned and gas can no
longer be supplied by the solenoid valve 40a. This enables the infrared heater to continue operating out in the field remote from any service until the job is completed. The thermocouple safety device 31 ensures that if the flame at the pilot burner 44 is extinguished, the flow of gas to the pilot burner 44 is automatically interrupted.

The electronic temperature control is actuated in the following manner. Firstly the main switch 36 is switched on. The digital display 42 of the temperature control will indicate the present temperature of the surface A to be heated and the digital display 38 will indicate whether or not the battery 37 has to be recharged. If one of the LEDs in the battery status visual display control 38 is showing red, the battery has to be re-charged. The timer switch 41 is switched on, the timer knob 40 is turned, thereby opening the solenoid valve 40a to supply gas to the radiators 13 which are ignited by each pilot burner 44. The ignition process operates in the following manner. When the solenoid valve 40a is opened, the pilot burners 44 ignite the gas/air mixture in those radiators 13 nearest the pilot light boxes 27 which initiates ignition of all the other radiators 13 down the respective rows and the burner-on light 43 glows orange. The green light 50 flashes throughout the heating cycle and is automatically switched off at the end of the cycle making it easier for an operator 51 (Figures 11 and 12) to see that the heating cycle has ended.

When the surface temperature measured by the infrared sensor reaches the predetermined value, i.e. the switching-off temperature is reached, the solenoid valve 40a will switch off the gas supply to the radiators.

The infrared heater 10 is disabled by turning the main switch 36 into the off position which closes the solenoid valve causing interruption of the gas supply to the gas infrared radiators 13 and switching off all the visual displays on the control panel 35. Finally, the two gas cylinder valves and the gas cylinder fixing ball valve are closed.

Further embodiments of the lightweight and larger infrared heaters 10, illustrated in Figures 17 to 21, differ from the embodiment shown in Figures 1 to 16 in that the supply conduits 23 are provided with 'U' bends (not visible), positioned approximately midway between the connector conduits 25, which allow for heat expansion of the conduits and provide easier access to the infrared heaters 13. A further difference is that the header conduit 29 is fixed to the gas cylinder fixing 19. Figures 18 and 20 illustrate a pressure governor 60 and an
associated valve 62 on the header conduit 29. Pins 64 are also provided for fixing the position of the legs 14. An infrared sensor 66 is shown in Figure 21.

Referring now to Figure 23, in which embodiment of a control panel 35, the variable timer knob 40 is on the front face of the control panel 35.

The system of the invention for the once-only repair of potholes and similar defects in bituminous bound surfaces utilises the following.

**Equipment and Materials**

- The infrared heater 10 illustrated in Figures 1 to 8.

- An asphalt rake with a shortened handle and a 9 inch rake head.

- GSB-99 bitumen rejuvenating liquid having the composition referred to in previously in the introduction.

- GSB-78 top coating liquid having the composition referred to in previously in the introduction.

- Cold new material consisting of a mixture of aggregate blend (63% stone and 29.4% sand), 2% bitumen, and 5.6% GSB-78.

- Black Rhino™ fine aggregate.

- Two hand held 10 litre capacity low-pressure sprayers, one for applying GSB-99 bitumen rejuvenating liquid and the other for applying GSB-78 top coating liquid.

- A mini single drum vibratory roller with a working width of 55cm for compacting the cold new material.
Application

- GSB-99: Using the 10 litre spray applicator, pressurised to 6 bar, an even spray is applied over the raked area at a rate of 0.5 to 0.8 ltr/m². This is typical for a 40mm depth. The rate of application will need to be adjusted by ± 20% if the asphalt or tarmacadom on visual inspection is deemed to be particularly aged or identified as rich in binder.

- GSB-78: Using the 10 litre spray applicator, pressurised to 6 bar, an even coating is applied over the total heated area at a rate of 0.5 to 0.8 ltr/m² ± 20%.

- Using the pepper pot method apply an even coating of Black Rhino™ fine aggregate over the entire area whilst the GSB-78 is still wet.

- In order to ensure the correct quantities are applied, the individual areas should be measured and the correct amount of material put into the equipment before spraying.

Application Considerations

- The repair process can be carried out in wet and damp conditions but should not be used in heavy rain. Excess water must be removed prior to starting the heating cycle.

- The heat and timing cycles should be set by the operative to the parameters set out in the table below for the various surfacing materials as identified.

- These figures are given as a guide and operational circumstances and experiences may dictate variations to those given. The maximum temperatures however should not be exceeded.

<table>
<thead>
<tr>
<th>Surface Material</th>
<th>Maximum Temperature (°C)</th>
<th>Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Rolled Asphalt</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>Macadams</td>
<td>170</td>
<td>8</td>
</tr>
<tr>
<td>SMA type materials</td>
<td>200</td>
<td>12</td>
</tr>
<tr>
<td>Surface dressed sites</td>
<td>160</td>
<td>10</td>
</tr>
</tbody>
</table>
• Care must be taken not to disturb the base course when exposing the heated wearing course.

• GSB-78 is a flammable material and should only be applied when the temperature of the repaired patched area is 50°C or below.

Heating Cycle

1. Position the infrared heater 10 of Figures 1 to 8 over an area of bituminous wearing course of asphalt for example to be repaired having a surface A. Set the infrared heater 10 to the correct height by adjusting the uprights 16 in the sleeves 18 if the heater 10 is free standing as illustrated or the height from the surface A using the lifting apparatus connected to the lifting means 28 if suspended from a transporting vehicle based upon site conditions and apply heat to area. Use the table above to set the timer and temperature controls according to the material of the surface being repaired.

2. Remove the heater 10 after an initial cycle and check that the workability of the material is sufficient to carry out the repair.

3. If the asphalt has not achieved this workability, replace the heater 10 and reheat for 2 minute cycles until workability is correct.

4. Make adjustments to the timer and temperature controls if necessary based on observations from the first cycle.

Exposing the Wearing Course

5. Break into the surface A with a shovel to produce a neat straight joint 100mm inside the perimeter of the heated area.

6. Thoroughly rake the surface A with the raking apparatus in order to expose the maximum surface area within the material. At this stage and only if necessary, remove any excess material as may be required to adjust finished levels. In the case of a pothole, rake the
existing material to a consistent level ready to receive a consistent thickness of the new cold material to the whole of the raked area.

**Application of GSB-99 Bitumen Rejuvenating Liquid**

7. Measure the exact amount of GSB-99 (0.5 to 0.8 litre/m²) into the sprayer and pressurise to 6 bar.

8. Apply the GSB-99 evenly onto the surface and fully discharge the contents of the sprayer.

9. Thoroughly rake in the GSB-99 to distribute evenly through the area making sure no puddles have formed.

**Working of the Joints Between the Edges of the Pothole and the Surface of the Wearing Course**

10. Add the cold new material as necessary to the surface and rake evenly, allowing a small surplus of new cold material above the existing level when raking to allow for compaction.

11. At the joints, merge the cold new material into the old material in order to create a seamless repair, making sure there are no high or low spots.

12. Compact the joints immediately using the roller to provide a seamless finish.

**Final Compaction**

13. Compact the joints immediately with the roller using vibration only when necessary.


15. Make further passes over the repair with the mini roller until cold new material has stabilised and the new surface is flush with the existing surface A.
16. Observe that there is no deviation in level between the new repair and the existing surface A and that there are no voids. Cross roll any evident bumps with the mini roller.

**Application of GSB-78 Top Coating Liquid and Black Rhino™ Fine Aggregate**

17. When the temperature of the repair has dropped substantially, (to approximately 50°C), GSB-78 top coating liquid can be applied uniformly to the surface.

18. Measure the exact amount of GSB-78 (0.5 to 0.8 litre/m²) into the sprayer and pressurise to 6 bar.

19. Apply GSB-78 evenly onto the surface of the “Total Heated Area” and fully discharge the contents of the sprayer using a straight edge as a guide.

20. Immediately apply Black Rhino™ fine aggregate using a spreader provided with the aggregate at 0.5kg / m² to the wet GSB-78.

21. Over application of the Black Rhino™ fine aggregate can reduce skid resistance and should be avoided.

22. When the GSB-78 is dry to the touch and the surface of the repair is cool to the touch, the repaired surface is in a suitable condition for traffic.

Various modifications may be made to the inventions described herein. For example different formulations of bitumen rejuvenating liquid, Gilsonite based liquid material and top coating liquid and different anti-skid resistant aggregates can be used. The larger infrared heater can comprise any number of units joined together, for example four units of different shapes which can join together to be generally square-shaped. The infrared heater 10 may be provided with a single pilot box 27.
Claims

1. A method of repairing a damaged area of a bituminous wearing course including:
   heating the damaged area with an infrared heater,
   raking the heated damaged area so as to mix highly oxidised top surface material of
   the damaged area with less oxidised sub-strata,
   applying a bitumen rejuvenating liquid composition to the raked heated damaged
   area,
   adding new material to the rejuvenated raked heated damaged area, and
   compacting the new material to provide a compacted repaired area of bituminous
   wearing course, characterised in that said new material is applied cold and is in the form of a
   composition including aggregate, bituminous material and a naturally occurring mineral
   asphalt based liquid material.

2. A method according to Claim 1, wherein before compacting the new material, the method
   further includes raking the cold new material to ensure mixing of the new material with the
   bitumen rejuvenating liquid composition and the material of the damaged area.

3. A method according to Claim 1 or Claim 2, including providing a further boost of bitumen
   rejuvenating compounds into the surface of the compacted repaired area and binding and
   sealing the surface of the compacted repaired area by applying a topcoating liquid consisting
   essentially of gilsonite, asphalt cement, solvent and antistripping agent to the surface of the
   compacted repaired area.

4. A method according to any one of the preceding claims, further including applying a fine
   aggregate to the surface of the compacted repaired area to increase skid resistance.

5. A method according to any one of the preceding claims, wherein said bitumen rejuvenating
   liquid composition is resistant to temperatures of up to 200°C and essentially consists of a
   cationic slow set emulsifier, a heavy paraffinic distillate solvent extract, a heavy naphthenic
   distillate solvent extract and water.
6. A method according to any one of claims 1 to 4, wherein said bitumen rejuvenating liquid composition is resistant to temperatures of up to 200°C and essentially consists of a cationic slow set emulsifier, a heavy paraffinic distillate solvent extract, a heavy naphthenic distillate solvent extract, a naturally occurring mineral asphalt and water.

7. A method according to Claim 5 or Claim 6, wherein the cationic slow set emulsifier is from 1 to 5 parts by weight of the composition, the heavy paraffinic distillate solvent extract and the heavy naphthenic distillate solvent extract is 30 to 80 parts by weight in total of the composition, and the water is from 10 to 60 parts by weight of the composition.

8. A method according to Claim 5 or Claim 6, wherein the cationic slow set emulsifier is from 1 to 5 parts by weight of the composition, the heavy paraffinic distillate solvent extract and the heavy naphthenic distillate solvent extract is 60 to 65 parts by weight in total of the composition, and the water is from 30 to 35 parts by weight of the composition.

9. A composition for use as a new material in a method of repairing a damaged area of a bituminous wearing course, said new material composition being in a cold state and including aggregate, bituminous material and a naturally occurring mineral asphalt based liquid material.

10. A composition according to Claim 9, wherein the bituminous material comprises less than 2.5% by weight of the new material.

11. A composition according to Claim 9 or Claim 10, wherein the naturally occurring mineral asphalt based liquid material comprises less than 5.6% by weight of the new material.

12. A composition according to any one of claims 9 to 11, wherein the aggregate comprises 92.4% by weight of the new material, the bituminous material comprises 2% by weight of the new material, and the naturally occurring mineral asphalt based liquid material comprises 5.6% by weight of the new material.
13. A composition according to any one of claims 9 to 12, wherein the aggregate blend comprises stone and sand, the stone comprising 68.2% of the aggregate blend and the sand comprising 31.8% of the aggregate blend.

14. A composition according to any one of the preceding claims, wherein the naturally occurring mineral asphalt based liquid material consists essentially of gilsonite, asphalt cement, solvent and anti-stripping agent.

15. A composition according to Claim 14, wherein the gilsonite and asphalt cement comprise 20 to 60 parts by weight of the gilsonite based liquid material, the solvent comprises 20 to 80 parts by weight of the gilsonite based liquid material and the anti-stripping agent comprises 1 to 5 parts by weight of the gilsonite based liquid material.

16. A composition according to Claim 15, wherein the solvent of the gilsonite based liquid material comprises petroleum kerosene/naphtha, VM&P naphtha and/or lactol spirits.

17. A composition according to Claim 14, wherein the gilsonite and asphalt cement are 35-45% by weight of the gilsonite based liquid material, the solvent comprising petroleum kerosene/naphtha, VM&P naphtha and lactol spirits is 50-60% by weight of the gilsonite based liquid material and the anti-stripping agent is up to 5% of the gilsonite based liquid material.

18. An infrared heater for use in repairing a damaged bituminous wearing course, said infrared heater comprising at least one radiator for applying heat to an underlying damaged bituminous wearing course, and control means for controlling the applied heat such that the heating temperature is defined by a lower predetermined limit and an upper predetermined limit.

19. An infrared heater according to Claim 18, wherein the control means is operative to supply flammable gas to the at least one radiator by automatically switching on the flow of gas until the upper temperature limit is reached, when the upper temperature limit is reached automatically switching off the flow of gas, and when the lower temperature limit is reached
automatically switching on the flow of gas again, whereby to apply a pulse of heat to the underlying damaged bituminous wearing course.

20. An infrared heater according to Claim 18 or Claim 19, wherein the lower predetermined limit is defined by a predetermined temperature drop relative to the upper predetermined temperature limit.

21. An infrared heater according to any one of claims 18 to 20, further comprising a heat sensor arranged to sense the temperature of the heat being applied to the underlying damaged bituminous wearing course.

22. An infrared heater according to Claim 21, wherein the control means is operative to compare the sensed temperature of the heat being applied to the underlying damaged bituminous wearing course with the said predetermined temperature limits and automatically to switch the flow of gas on or off according to the predetermined temperature limits.

23. An infrared heater according to any one of claims 18 to 22, further comprising a timer automatically to switch the flow of gas off after a predetermined time interval.

24. An infrared heater according to any one of claims 18 to 23, wherein the at least one radiator comprises a housing defining a gas receiving chamber which is closed by a mesh cover, and a diffuser having a mesh surface in the chamber on which surface the gas ignites to heat the damaged bituminous wearing course.

25. An infrared heater according to anyone of claims 18 to 24, further comprising a multiplicity of said at least one radiators arranged in the form of an array.
Figure 23