

TITLE: COMPACTION DEVICE

The present invention relates to a compaction device, notably to one for compacting weak, uneven ground to produce a firmer level surface.

5 BACKGROUND TO THE INVENTION

It is often desired to compact ground to produce a firmer, level surface; for example to prepare ground upon which a structure is to be built or to repair structures, such as roads or runways, which have been damaged. On a small
10 scale, the ground can be tamped firm with a manual tamping tool or a percussion tamper. However, such devices are suitable only for small areas and do not achieve any significant compaction of the ground at depths more than a few millimetres below the surface.

15 Where large scale compaction of the ground is required and the compaction has to extend 25 cms or more into the ground, this has hitherto been achieved by dropping a weight of five tonnes or more from a height of five metres or more onto the ground to be compacted. However, not only
20 is this a hazardous operation, but much of the energy imparted to the weight is dissipated due to mechanical and impact losses without achieving useful compaction of the soil. The process is also slow and cumbersome and causes rapid wear to the operating machinery. Furthermore, such
25 a process cannot be used successfully to restore ground around a crater in a paved surface, since it causes the rim of the crater to collapse into the crater.

In order to optimise the compactive force, it is desirable to apply the force over a comparatively wide area and at
30 frequent intervals. It would therefore be desirable to use a conventional reciprocating system, similar to those used

in a pile driver, to drive the weight and to apply the force of the weight to the ground through a broad compaction foot or plate. However, whilst such a mechanism might find use in compacting substantially level ground, it would not have been expected to operate on uneven ground as is usually encountered in ground improvement operations. This is because the broad foot would strike the ground initially at the highest point of the ground surface underlying the foot. This would usually be off-centre and this would impose a twisting moment on the weight and its support mechanism. In view of the weights and energies involved, this twisting moment would be expected to damage the hammer mechanism. If the foot were attached to the weight or an intermediate follower by a ball or similar coupling which allowed the foot to adopt an orientation parallel to the overall slope of the ground, the twisting moment might be reduced. However, the impact force from the weight would have a component which acts normally to the overall slope of the ground, and this would cause the foot to be driven following that line of action. That is, the foot would not level the ground but would tend to preserve the slope of the ground. This would be unacceptable. Furthermore, if the foot is carried with the weight, a significant proportion of the impact force of the weight drop is dissipated as the foot strikes the ground and aligns to the slope of the ground surface.

We have devised a device for compacting uneven ground which reduces the above problems and enables a rapid stroke hammer mechanism to be used to compact the ground.

30 SUMMARY OF THE INVENTION:

Accordingly, the present invention provides a device for compacting and levelling ground, which device is adapted to be mounted upon a mechanism for supporting the device and

manoeuvring it over the ground, the device comprising a weight, a ground engaging foot member and a mechanism for vertically reciprocating the weight so as to apply a series of ground compacting blows to the ground engaging foot member, characterised in that the device is configured so that, when the foot member acts upon sloping ground, the ground compacting blow of the weight acts through a point radially off set from the line of reciprocation of the weight, which point is located on the uphill side of the line of reciprocation of the weight; and means are provided for accommodating at least part of the horizontal component of any twisting moment caused by the blow of the weight.

Preferably, the foot member is mounted so that it is adapted to adopt an orientation substantially parallel to the overall slope of the ground underlying the foot member, notably by mounting the foot member by means of a floating linkage directly or indirectly upon the base of the means for guiding the line of travel of the weight. It is particularly preferred that the foot member be mounted by means of the floating linkage upon a follower member driven by the weight. It is also preferred that the follower has a base face engaging the upper face of the foot member which is of larger diameter than the lower face of the weight acting on the follower. In this way the impact force of the ground compacting blow of the weight acts through a portion of the upper face of the follower member which is radially off set from the line of travel of the weight, and the effective line of action of the impact force of the weight is further off set at the interface between the follower and the foot member.

The mechanism used to drive the weight which is to act on the compaction foot member can be of conventional reciprocating hammer design and construction. Thus, a preferred mechanism comprises a weight moving substantially

vertically in guide rails or the like and driven by a single or double acting pneumatic, steam or hydraulic cylinder or diesel mechanism. The hammer mechanism is adapted to be mounted on a suitable support and transport mechanism. This can be a mobile crane or other motorised chassis which can be manoeuvred over the ground. The transport means preferably takes the form of a tractor unit having the compaction device mounted at the front end thereof and which also carries the necessary power units, hydraulic fluid tanks and control systems for operating the hammer mechanism.

The foot member through which the weight impact force acts can take a number of forms. For example it can be a radially enlarged foot to the weight so that the ground compaction foot travels with the weight and is rigidly connected thereto. However, as detailed below, it is preferred to provide a floating or articulating linkage between the foot of the weight and the ground compaction foot member so that the foot member can adopt an orientation at which it follows the overall angle of slope of the ground underlying the foot when in contact with the ground. The foot member thus preferably comprises a generally planar plate member, typically a circular, square or rectangular plate made from steel or other suitable material. The plate member extends in at least one transverse direction beyond the diameter of the foot of the weight so that the impact blow of the weight can act through a portion of the foot member which is radially off set in the uphill direction from the line of travel of the weight. The optimum dimensions for the plate member can be determined for any given ground and operating conditions. Typically, a plate member of from 1 to 3 metres diameter will give satisfactory results in a wide range of conditions.

The device of the invention also comprises means for accommodating at least part of the horizontal component of the blow of the weight. Where the foot member is rigidly mounted to the foot of the weight, where it is provided by
5 a splayed foot to the weight, or where the degree of relative articulation between the foot member and the weight is limited, for example less than 5° about the line of travel of the weight, it will usually be necessary to provide means in the mounting of the device on the tractor
10 unit for accommodating the horizontal component of the blow of the weight. This can be achieved by mounting the device of the invention on the tractor unit by a resilient mounting which allows the base of the device to be held substantially fixed but which allows the upper end of the
15 device (the hydraulic cylinder and weight travel guide rails) to move away from the vertical to adopt a position aligned substantially normal to the slope of the ground against which the ground compaction foot member strikes, thus minimising the twist which is applied to the support
20 structure of the device.

However, we have surprisingly found that there is substantially no horizontal component of the blow of the weight which has to be accommodated when the mounting of the ground compaction foot member is capable of sufficient
25 articulated to allow it to conform to the slope of the ground to be compacted at the downward stroke of the weight. Thus, the device of the invention can be mounted securely in the substantially vertical position on the tractor unit, thereby avoiding the need to permit the upper
30 end of the device to swing in its mounting. It will be appreciated that the mounting of the device may permit some pivoting of the device so as to enable the device to act at an angle to the vertical if desired. For example, the device can be mounted by means of a horizontal pivot pin or
35 the like and be provided with hydraulic rams to enable it

to be pivoted fore and aft to align the axis of action of the weight according to the ground conditions.

We believe that the reduction in the horizontal component of the impact force of the weight which has to be accommodated arises at least in part because the impact force acts off-centre from the line of travel of the weight and through a point on the foot member which lies on the uphill side of the line of action of the weight. As a result, a larger proportion of the impact force acts on the uphill side of the foot member and will tend to pivot the foot member. This pivoting action not only absorbs at least part of the horizontal twist on the device due to the horizontal component of the impact force, but also causes the soil on the uphill side of the foot member to be compacted more than the soil on the downhill side of the foot member. Thus, by allowing articulation between the foot of the weight and the ground compaction foot member and by causing the impact force to act on the uphill side of the foot member, the device of the invention reduces the problems hitherto expected with the use of a vertically acting weight. Furthermore, the device of the invention progressively levels the ground it acts on, so as to produce a substantially level surface. The free articulation between the foot of the weight and the foot member provides a means for self-adjusting the off set of the position of the impact blow on the foot member and thus inherently biasses the operation of the device towards a stroke acting normally to the plane of the ground.

The articulation between the foot of the weight and the foot member can be achieved in a number of ways, having regard to the requirement that the impact force from the weight must act on the foot member off set from the line of travel of the weight and on the uphill side of that line of travel. Thus, the base of the weight can carry the plate

forming the foot member loosely attached thereto by means of a floating or articulating linkage, for example incorporating spring or other resilient mountings which allow the foot member to adopt a tilted orientation with respect to the base of the weight as the foot member bears against the ground. Alternatively, the foot member can be retained upon the foot of the weight by means of a radially projecting flange on the foot of the weight engaging with a corresponding radially inwardly directed flange carried by an upstanding sleeve member carried by the foot member and vice versa; or by means of a loose fit between one member and a collar carried by the other.

In a particularly preferred embodiment, the foot member is separated from the base of the weight by an intermediate follower member which is struck, either directly or via a cap member carried by the follower member, by the base of the weight. The follower is preferably supported and guided in a guide assembly, which is conveniently a continuation of the guide rail assembly in which the weight travels. In this way, the weight can be raised without the need to carry the foot member assembly with it. The foot member preferably comprises a generally flat plate carrying on its upper face an upstanding annular sleeve, which may be continuous or discontinuous; for example in the form of a series of posts in a ring. The annular sleeve carries at or adjacent its upper lip an annular member to provide an inwardly directed flange. Located within the sleeve is the follower member, whose upper face is exposed above the annular member to provide the surface against which the base of the weight strikes. The follower member carries a radial flange or series of projections which engage with the annular member on the sleeve so as to retain the foot plate upon the follower member. The follower member is attached, for example by chains or the like, or by means of inter-engaging radial lugs, hooks or the like on the frame

within which the weight travels which engage sockets or the like on the follower, or vice versa, so that the follower is free to move axially with respect to the weight support frame, but can be lifted off the ground when the hammer
5 assembly is raised.

As indicated above, the follower member can carry a cap member which is interposed between the bottom face of the weight and the upper face of the follower. The cap member typically comprises a generally cylindrical member having
10 a socket or recess in its upper face to receive the foot of the weight and a socket or recess in its lower face into which the upper end of the follower member engages. The sockets or recesses serve to locate the cap and follower members transversely. The sockets or recesses can be
15 provided with cushioning material as is conventional in pile driving equipment between impact faces, and/or such cushioning can be provided on the opposing impact faces of the weight and the follower member.

The parts forming the foot member are sized and shaped so
20 that there is an overall articulation of from 5 to 20° within the foot member assembly about the line of travel of the weight so that the ground engaging face of the ground compaction foot member can accommodate slopes in the ground of up to 20° or more. As indicated above, it is preferred
25 that the articulation linkages be floating so that the components of the foot member can freely move in all directions with respect to one another due to the floating linkages between them.

As stated above, the impact force of the weight acts on the
30 foot member radially off set from the line of travel of the weight and on the uphill side of that line so that the foot member is driven proportionally more into the higher areas of the ground than the lower areas. This effect can be

achieved by the use of a substantially cylindrical weight and a cylindrical foot assemblies, since the contact point at the interface between the base of the weight and the upper face of the foot member or follower will occur at a portion radially off set towards or at the edge of the base of the weight, ie. off set by the radius of the base of the weight from the centre line of the travel of the weight. However, in order to increase the effect, it is preferred that the follower member have a splayed configuration so that its lower edge contacts the upper face of the foot plate some distance, typically 30 to 75 cms, radially off set from the centre point of the foot plate. The larger the diameter of the lower face of the follower member, the larger the off set to the point at which it contacts the foot plate and the greater the bias towards compacting the uphill areas of the slope of the ground.

Thus, it is usually preferred that the relative transverse dimensions of the impact interfaces between the base of the weight and the various components of the foot assembly increase progressively from the base of the weight to the foot plate so that the effective line of action of the impact force from the blow of the weight is off set progressively radially from the line of travel of the weight at each interface. Typically, the off set from the line of travel of the weight at the interface between the base of the weight and the upper face of the cap member will typically be from 20 to 60 cms, the off set at the interface between the cap and follower members will be from 20 to 60 cms, and the off set at the interface between the base of the follower and the ground compaction foot member will be from 30 to 75 cms. We believe that this progressive increase in the off set also reduces the twisting moment on the device.

As the weight strikes the ground compaction foot member or

the intermediate cap member, the impact force of the blow of the weight is directed through the off set point of contact to bias the compaction force of the device of the invention towards the uphill areas of the ground area underlying the foot member. As a result, especially where the foot member rests upon the slope of the ground at the moment of impact of the weight, the foot member will tend to pivot about its lower edge and progressively to level the slope of the ground. With repeated blows of the weight, the ground assumes a level configuration until the foot member adopts a substantially horizontal orientation, at which point the device will be compacting a substantially level surface with the impact forces of the weight acting along the line of travel of the weight through the centre point of the foot member. Such an assembly thus self biasses towards a level ground situation without the need for any adjustment of the foot member or the cap member during use.

The device of the invention finds use wherever it is desired to level and compact ground or other surfaces. Thus, it finds use in repairing damaged roadways or runways and is of especial benefit in such uses in that it can be used to compact the existing surface around a damaged area with a reduced risk of deforming the rim of the existing surface into the damaged area.

DESCRIPTION OF THE DRAWINGS:

The device of the invention will now be described by way of illustration with respect to the preferred form thereof as shown in the accompanying drawings in which Figure 1 is a side elevation of the device mounted on a tractor unit; Figure 2 is a front elevation of the device of Figure 1; Figure 3 is a detailed view of the foot assembly for use in the device of Figure 1; and Figure 4 illustrates the

articulation of the foot assembly of the device of Figure 1 during use.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

The device of the invention comprises a weight 1, for example a 7 tonne drop weight, raised and lowered in a frame 2 by means of a hydraulic ram 3 anchored in frame 2 by any suitable means. Frame 2 is supported by a secondary frame 4 which is carried on the front end loader arms 5 of a tractor unit 6. The tractor unit 6 enables the device to be transported to the operating site and manoeuvred around the area to be levelled and compacted. The front end loader arms 5 can be adjusted in the conventional way to raise or lower the device and to alter its vertical orientation if required. However, raising or lowering the arms 6 carries the frame 2 on a curved path. In order that the final vertical adjustment of the device can be achieved linearly, frame 2 is connected to the secondary frame 4 by means of hydraulic rams 7 which raise or lower frame 2 with respect to frame 4. The rise and fall of weight 1 is guided by guide rails forming part of frame 2.

At the foot of frame 2 is located a foot assembly which is to be driven by the weight 1. The foot assembly comprises an upper cap member 10 which is located upon frame 2 and is retained upon the frame by hooks 8, lugs or other means on the frame 2 engaging co-operating sockets, circumferential grooves or the like on the cap member 10. The cap member has an axial socket 11 in its upper face into which the base of the weight 1 engages in a loose fit permitting up to 5° articulation between the weight and the cap 10. The cap 10 has an axial socket 12 in its lower face into which the axial stem 13 of a follower member 14 locates. Again, it is preferred that the stem 13 be a loose fit within socket 12 so that there is up to 5° articulation between the

cap 10 and the follower 14. If desired, cushioning material 15 can be located between the impact interfaces between the weight 1, the cap 10 and the follower 14.

5 The follower member 14 preferably has a generally frusto-conical shape so that its lower face has a larger diameter than the upper end of stem 13, as shown. It is also preferred that the follower 14 be attached to the frame 2 by chains 16 or other suitable means, so that the follower 14 can be lifted with frame 2. The chains 16 are
10 preferably connected to the follower member 14 as close to the centre line thereof as is practicable.

The follower member carries at its lower end a basal ground compaction foot plate 20 which is attached to the follower 14 by a floating linkage to permit articulation between
15 them. This is the major articulation in the foot assembly, and typically permits up to 15° articulation. As shown in Figures 3 and 4, the linkage can be achieved by means of an annular upstanding skirt 21 on the upper face of plate 20, preferably with external buttress supports 22. Preferably,
20 the plate 20 and the skirt 21 are of a circular plan configuration with the skirt 21 located symmetrically about the centre point of the plate. The follower 14 locates within the skirt 21 and is retained as a loose fit in the skirt by any suitable means, for example by an inwardly
25 projecting annular flange 23 located at or adjacent the upper lip of skirt 21 which prevents the broader foot of follower 14 from escaping from the open top of the skirt.

The foot assembly components are sized and shaped so that the plate 20 can tilt at up to 20° to the axis of the foot
30 assembly.

As shown in Figure 1, the foot assembly can adopt a position at which the foot plate 20 lies parallel to the

slope of the ground to be compacted, whilst the frame 2 remains substantially vertical. As shown in Figure 4, the foot of the follower 14 engages the upper face of the plate 20 at a point X radially off set from the centre point of the plate and off set to the uphill side of the line of travel of weight 1. When the weight strikes cap 10, the impact forces are transferred through the cap to the follower and hence to the plate 20 at point X. This will impart a biased force to the plate 20 causing more compaction at the uphill side of plate 20 than at the lower side. This will tend to cause plate 20 to pivot about its lower edge, point Y, to provide a bias to level the ground. As the plate 20 adopts a more horizontal orientation, the bias diminishes until the horizontal is reached, at which point the plate 20 will be driven directly along the line of travel of the weight and hence along the line of action of the impact force of the weight. Any tendency to adopt a non-horizontal position and hence form a non-level area will be corrected by the opposing bias which would then be created by moving the line of contact between the follower 14 and the plate 20 away from the line of travel of the weight.



CLAIMS:

1. A device for compacting and levelling ground, which device is adapted to be mounted upon a mechanism for supporting the device and manoeuvring it over the ground,
5 the device comprising a weight, a ground engaging foot member and a mechanism for vertically reciprocating the weight so as to apply a series of ground compacting blows to the ground engaging foot member, characterised in that the device is configured so that, when the foot member acts
10 upon sloping ground, the ground compacting blow of the weight acts through a point radially off set from the line of reciprocation of the weight, which point is located on the uphill side of the line of reciprocation of the weight; and means are provided for accommodating at least part of
15 the horizontal component of any twisting moment caused by the blow of the weight.
2. A device as claimed in claim 1, wherein the foot member is mounted so that it is adapted to adopt an orientation substantially parallel to the overall slope of
20 the ground underlying the foot member when in contact with the ground, whereby the compacting blow of the weight is adapted to act upon the upper face of the foot member through a radially outward portion of the foot member which is offset from the centre point of the foot member.
- 25 3. A device as claimed in either of the preceding claims, wherein the foot member is mounted by means of a floating linkage upon the base of a means for guiding the line of travel of the weight.
- 30 4. A device as claimed in any one of the preceding claims, wherein a follower member is provided intermediate the weight and the foot member, which follower member is adapted to permit articulation of the foot member about the



line of travel of the weight.

5. A device as claimed in claim 4, wherein the follower member is mounted by means of a floating linkage at the base of a means for guiding the line of travel of the weight, the foot member being mounted by means of a floating linkage upon the base of the follower member so as to permit articulation of the foot member about the line of travel of the weight.

6. A device as claimed in claim 5, wherein the floating linkages between the travel guide means and the follower member and between the follower member and the foot member are provided by means of engaging one member within a annular member carried by the other.

7. A device as claimed in any one of claims 2 to 6, wherein the follower member has a base face engaging the upper face of the foot member which is of larger diameter than the lower face of the weight acting on the follower member, the foot member having a ground engaging face which extends in at least one direction beyond the base face of the follower member.

8. A device as claimed in any one of the preceding claims, wherein the articulation between the foot member and the line of travel of the weight is from 5 to 20°.

9. A device as claimed in any one of claims 4 to 8, wherein a cap member is interposed between the follower member and the base of the weight, which cap member permits articulation between the weight and the follower member.

10. A device as claimed in any one of the preceding claims, wherein the line of effective action of the weight impact force is adapted to act through a contact portion of



- the base face of the weight which is located radially outwardly from the line of travel of the weight, and the impact force acts upon the upper face of the foot member through one or more intermediate members through contact portions of the base faces of those intermediate members which are each located radially outwardly from the line of travel of the weight with respect to the contact portion of the preceding member so as to provide a radial off set in the line action of the weight between successive members.
11. A device as claimed in claim 10, wherein the radial off set is from 20 to 60 cms at the interface between the base of the weight and the upper face of the cap member and at the interface between the base of the cap member and the upper face of the follower member; and the radial off set is from 30 to 75 cms at the interface between the base of the follower member and the upper face of the foot member.
12. A device according to claim 1, substantially as hereinbefore described.
13. A device as claimed in any one of the preceding claims, substantially as hereinbefore described with respect to and as shown in the accompanying drawings.
14. A method for compacting ground, characterised in that a device as claimed in any one of the preceding claims is used to compact and progressively level the ground.
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