SYSTEM FOR DETECTING THE DEGREE OF COMPACTION OR RESISTANCE TO PENETRATION OF SOIL

The present invention relates to a system; notably to a system for detecting the movement of a compactor head or other article driven onto or into the ground by a reciprocating weight, so as to determine the extent of compaction of the ground by a blow of the weight or the resistance of the ground to penetration by the article being driven into it.

Ground is often of inadequate strength for the purpose to which it is to be put, for example where it has been disturbed or infilled, and is to be used to support a building, roadway or other structure. It is therefore necessary to compact the ground to provide a firm substrate upon which the structure can be constructed.

Conventionally, this has been done by dropping a heavy weight from a height of several metres onto the ground. The objective of such a system is to achieve impact on the ground at a high impact velocity since it has been believed that this is necessary to achieve compaction to any significant depth in the ground. This system has the disadvantages that it imposes particularly onerous loads on the operating machinery and that it is dangerous to people and equipment in the immediate vicinity of the falling weight.

We have found that satisfactory results can often be achieved and a significant extent of depth of compaction can be achieved if the ground is struck repeatedly with a smaller weight. We have devised a mechanism whereby a ground engaging compaction foot can be driven onto the

ground by means of a reciprocating ram driving a weight which impacts with the foot - see our co-pending British Patent Application No 2,241,461 A. This enables the ground to be levelled and compacted using a compact and readily manoeuvrable system which is inherently more safe and causes less wear on the operating equipment than previous methods of operation.

However, it is desirable to ensure that the ground is compacted to a substantially uniform extent across the area of a site to avoid the risk of differential settling of the ground. This is usually done by an operator driving a probe into the compacted soil using a known impact weight and observing the extent to which the probe is driven into the ground. This is time consuming and cannot give an indication of the extent of compaction achieved during operation of the compaction system. Alternatively, the site is compacted to a given level and it is assumed that the extent of compaction at any given point will be adequate for the load which it is to bear. However, this is unsatisfactory since ground levelled to the common level may have been compacted to a greater or lesser extent than other areas of ground elsewhere on the site.

We have devised a system for detecting the extent of movement of the compaction foot at each blow of the driving weight of a compaction device so as to provide a direct indication of the extent of compaction of the soil onto which the foot is being driven and thus when compaction reaches a desired level. The invention provides a simple and effective means whereby an operator can assess when adequate compaction has been achieved at any given point during the operation of the compactor, and thus when the compactor should be moved to a different location, without the need to interruption the compaction process as hitherto.

SUMMARY OF THE INVENTION:

Accordingly, the present invention provides a system for detecting the degree of compaction or resistance to penetration of soil during the operation of the system, which system comprises an hydraulic ram for repeatedly reciprocating a weight in a guide member so as to impart repeated impact blows to an impact member which is to be driven onto or into the ground by the said repeated impacts; a sensor means adapted to give an electrical output responsive to the relative movement of the impact member with respect to another member whose vertical position relative to the surface of the ground into or onto which the impact member is driven remains substantially constant or varies in a known manner; and display means responsive to said sensor means for indicating the incremental and/or cumulative extent of movement of the impact member with respect to the surface of the ground.

Preferably, the system comprises an hydraulically driven ram adapted to reciprocate the weight in a guide frame so as to strike a pile cap which drives a pile into the ground, or to strike a compaction foot which is driven onto the ground surface to level and compact it. For convenience, the invention will be described hereinafter in terms of a soil compaction device utilising an hydraulic ram to reciprocate a weight against a compaction foot carried at the base of a guide frame within which the weight travels, the guide frame being carried upon a ground travelling support, for example a crawler tractor chassis.

During operation of the compaction device, the hydraulic ram lifts the weight up the guide frame during the lift stroke of the ram; and allows the weight to fall under gravity during the fall stroke of the ram to strike the upper face

of the compaction foot. Preferably, the fall stroke of the ram occurs when high pressure fluid is not fed to the ram and the weight falls under gravity. However, the ram may be a double acting ram so that the weight is driven downwardly by the ram during its fall stroke. For convenience, the invention will be described hereinafter in terms of a single acting ram in which high pressure fluid is fed to the cylinder of the ram during its lift stroke.

The ram lifts the weights and allows it to fall onto the compaction foot resting on the ground. The compaction foot is driven into the ground and rebounds slightly, depending upon the extent of compaction of the soil and the nature of the soil. The looser the soil, ie. the less compact and elastic the nature of the soil, the greater the rebound. We have found that by monitoring the rebound and/or the absolute movement of the foot from one blow to the next provides, a true indication of the extent of compaction of the soil is provided. However, for some soils, notably those high in clay content, the extent of rebound is reduced since the soil does not behave elastically. In this case, the extent of compaction is reflected in the absolute movement of the compaction foot from one blow to the next. It is preferred to use the system of the invention on soils which exhibit elastic behaviour, preferably on soils which do not exhibit a plastic as opposed to elastic behaviour, and to monitor both the absolute movement of the compaction foot and the rebound at each impact blow.

In the system of the invention, the absolute movement of the compaction foot, or a member associated therewith, and/or the extent of the rebound at the end of the fall stroke of the weight are monitored. In order to reduce the effects of the dynamic forces and reactions of the driving mechanism upon the observed relative position of the sensors used to

monitor the rebound and absolute position of the foot, it is preferred to monitor the absolute position of the compaction foot or a member associated therewith when there is no force from the ram acting on the weight. Thus, the monitoring of the rebound and absolute position of the compaction foot can be carried out at the end of the lift stroke of the ram when the weight is still rising, but under its own inertia (the overrun), or during the free fall of the weight; in both cases there is no dynamic reaction between the ram and compaction device which might otherwise affect the absolute position of the sensors used. The load on the ground is the mass of the weight, the guide frame and the remainder of the compaction device (which remains substantially constant during operation of the compaction device) and there is little or no additional dynamic load or reaction on the ground. The position of the sensor relative to the ground will thus be substantially constant. However, the absolute position of the compaction foot or guide frame may be monitored at other times during the cycle of operation of the ram, but means will then be required to compensate for any movement of the sensor due to the varying dynamic load exerted on the sensor mounting. For convenience, the invention will be described hereinafter in terms of sensing the position of the compaction foot or guide frame when no dynamic load is being applied to it by the ram.

The sensor means is preferably mounted on the support structure carrying the guide frame so that its position relative to ground level remains substantially constant during the compaction of the soil. Thus, the sensor is conveniently mounted on a second generally upright support frame upon which the guide frame is mounted so that the guide frame travels generally parallel to the longitudinal axis of the support frame as the compaction foot moves downwardly with the ground level as it is compacted, the

support frame remaining at substantially the same height with respect to the ground level during the compaction process. However, the sensor can be mounted on a ground travelling chassis upon which the support frame is mounted, or elsewhere where its position relative to the ground surface during the compaction blow remains substantially constant. For example, a laser can be mounted on a support driven into the ground at some point on the site so that the laser beam emitted from the laser provides a datum level against which movement of the compaction foot or the pile cap can be referenced.

It will also be appreciated that the sensor can be mounted on the compaction foot or the guide frame and the sensor then used to detect the position of the moving compaction foot or guide frame relative to the position of the static support frame, chassis or a ground supported sensor. For convenience, the invention will be described hereinafter in terms of a sensor mounted statically upon the support frame, which detects the passage of one or more indicia carried by the compaction foot or, more preferably, its guide frame since this travels with the compaction foot as it is driven into the ground.

The sensor is preferably one which senses the passage of a predetermined point on the guide frame carrying the compaction foot past the sensor. This point can be identified by a change in shape or physical nature of the guide frame, for example one or more notches on the frame or a specified cross member of the frame which are detected as they travel past a contact or non-contact sensor, for example an optical sensor, carried by the support frame. Alternatively, the sensor can detect one or more indicia affixed to the guide frame, for example a series of reflective strips or discs whose passage is detected

optically, or a series of magnets whose passage is detected by a Hall effect sensor, a reed switch or the like. Alternatively, the sensor can be a transducer, notably a linear transducer, for example a line connected to the guide frame which unwinds from a spool to cause the spool to rotate upon a screwed shaft to drive a rheostat or a pulse generator or the like so as to provide an electrical signal whose value varies with the position of the guide frame relative to the support frame. Such a sensor observes the terminal position of the travel of the guide frame and can also be used to measure the rebound which occurs at the end of the fall stroke of the weight.

Many suitable forms of sensor mechanism are commercially available and have been used in hydraulic pile drivers to measure the position of the hammer weight relative to a pile cap so as to control the operation of the valve mechanism regulating the flow of high pressure fluid to and from the hydraulic cylinder. However, in such applications, the sensors have been used to detect the internally related relative positions of two moving members within the envelope of the pile driver so as to ensure a uniform height of lift of the weight at each stroke of the hydraulic cylinder. The sensors have not been adapted to relate to an external factor, and their relative position to the ground level has been of no relevance. In the present invention the position of the compaction foot or its guide frame above the ground level is determined and this will vary during operation of the compactor. The sensor detects the decrease in movement of the compactor foot or the guide frame as the soil resistance increases as it becomes more compact and the output from the sensor thus provides a direct measure of the extent of compaction of the soil. As stated above, the movement being monitored can be solely the progressive vertical movement of the guide frame or the compaction foot

which becomes smaller from one blow to the next as the soil is compacted. However, it is preferred to monitor both the absolute movement and the rebound.

Accordingly, the invention also provides a method for detecting the resistance of the soil to an impact member driven into or onto it, which method comprises observing the movement of a reference point on the impact member relative to the ground level using a system of the invention. Preferably, the method is applied to the compaction of soil having an elastic character and both the absolute vertical movement and the rebound of the article at the end of each driving impulse are measured and compaction is halted when the extent of vertical movement of the reference point and the degree of rebound reach pre-determined minimum values. It is also preferred to observe the position of the reference point at a moment during operation of the mechanism driving the impact member into or onto the soil when no dynamic forces are acting between the mechanism and the impact member.

DESCRIPTION OF THE DRAWINGS:

To aid understanding of the invention, a preferred embodiment thereof will now be described by way of illustration with respect to the accompanying drawings in which Figure 1 is a diagrammatic side view of a compactor for use in the invention; Figure 2 is a diagrammatic detailed view of a sensor for use in the compactor of Figure 2; and Figure 3 is a diagrammatic representation of the output from the sensor of Figure 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

A compactor comprises a crawler or wheeled tractor chassis

1 carrying a generally upright support tower 2 by means of arms or hydraulic rams 3, 4 which can be raised or lowered to adjust the height and tilt of tower 2. Tower 2 carries a guide frame 5 slideably mounted or journalled thereon for axial movement with respect to the tower. A winch or other means (not shown) is provided for raising or lowering the guide frame on the tower.

The guide frame 5 carries an hydraulic ram 6 located at its upper end together with conventional fluid control valves, accumulators and control systems (not shown). The piston rod 7 of ram 6 extends downwardly to drive a weight 8 slideably journalled for axial movement on the guide frame 5. The foot of the guide frame 5 carries a compaction foot 9 against which the weight 8 strikes at the end of its downward travel. Foot 9 bears against the ground surface and progressively compacts the soil with each blow of the weight 8 against the upper face of the foot.

As shown in Figure 2, the guide frame 5 can carry a series of magnets 10 which trigger electrical pulses as they pass a Hall effect sensor 11 mounted on the support tower 2 as the guide frame moves upon tower 2. The pulses emitted by sensor 11 indicate the extent of travel of the guide frame and thus the terminal position of the frame and the rebound which may occur at the end of the fall stroke. Alternatively, the guide frame 5 can be connected by a wire or line 20 to a spool 21 rotatably mounted on a screw threaded rod 22 carried by tower 2. As the guide frame 5 rises and falls with respect to the tower 2, the spool 21 is rotated. The spool 21 can be spring biassed so that the line 20 is rewound as the guide frame 5 rises. This can be used to move rod 22 axially to adjust a rheostat to vary a voltage or current to provide an electrical signal corresponding to the terminal position reached during movement of the frame

5. Alternatively, the rotation of spool 21 can actuate a counter or pointer arm which can be used directly to give a visual display to the operator or can be used to generate other signals using conventional signal processing techniques to monitor the terminal position of the guide frame 5.

The output from the sensor 11 or the rheostat can be used to provide a visual display to the operator of the compactor, indicating the degree of compaction achieved at each blow of the weight 8. The operator can thus readily perceive when the compactor has achieved the desired effect and should be moved to compact another location. The output from the sensor or rheostat can be fed to an electronic or other means to give an audio or visual signal when the change in terminal position and or rebound of the guide frame 5 reaches a pre-determined minimum value to indicate when the desired compaction has been achieved and/or to provide a record of the compaction process for future reference. The extent of compaction can be monitored without interrupting the operation of the compaction device and the extent of compaction can be accurately controlled to give substantially uniform compaction over the area of a site directly by the operator of the compactor.

As shown in Figure 3, the output from the rheostat driven by the linear transducer 20, 21, 22 of Figure 2 will have values A and B for each impact blow of the weight, corresponding respectively to the position of the frame 5 at the lowest point on its travel at each blow and the rest position of the frame after any rebound and before the weight is raised by the ram. As the ground becomes more compacted, the change in the value of the signals A approaches a constant indicating that little movement of the frame 5 occurs at each blow. The difference between values

A and B will also decrease as the amount of relaxation of the compacted soil between blows, and hence the re-bound, decreases. Either or both of these relationships can be used to determine when the soil has been compacted to the desired extent.

It will be appreciated that the signals of the type shown in Figure 3 can be processed further using conventional signal processing technology and equipment to provide a digital or linear display to the operator.

WHAT WE CLAIMS IS:

1. A system for detecting the degree of compaction or resistance to penetration of soil during the operation of the system, which system comprises an hydraulic ram for repeatedly reciprocating a weight in a guide member so as to impart repeated impact blows to an impact member which is to be driven onto or into the ground by the said repeated impacts; a sensor means adapted to give an electrical output responsive to the relative movement of the impact member with respect to another member whose vertical position relative to the surface of the ground into or onto which the impact member is driven remains substantially constant or varies in a known manner; and display means responsive to said sensor means for indicating the incremental and/or cumulative extent of movement of the impact member with respect to the surface of the ground for successive impact blows of the weight on the impact member

2. A system as claimed in claim 1, wherein the system comprises a soil compaction device utilising an hydraulic ram to reciprocate a weight against a compaction foot carried at the base of a guide frame within which the weight travels, the guide frame being carried upon a ground travelling support mechanism.

3. A system as claimed in claim 2, wherein the terminal position of the travel of the compaction foot or the guide frame is adapted to be observed by one or more sensors mounted on or in association with the compaction foot and/or the guide frame which are adapted to observe one or more indicia carried by the support mechanism, or vice versa.

4. A system as claimed in either of claims 1 or 2, wherein the position of the impact member is sensed by a linear

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transducer.

5. A system as claimed in claim 1, substantially as hereinbefore decribed with respect to Figures 1 and 2 of the accompanying drawings.

6. A method for detecting the resistance of the soil to an article driven into or onto it, which method comprises observing the movement of a reference point on the article relative to the ground level using a system as claimed in any one of the preceding claims.

7. A method as claimed in claim 6, wherein method is applied to the compaction of soil having an elastic character and both the absolute vertical movement and the rebound of the weight at the end of each driving impulse are measured and compaction is halted when the extent of vertical movement of the reference point and/or the degree of rebound reach pre-determined minimum values.

8. A method as claimed in either of claims 6 or 7, wherein the position of the reference point is observed at a moment during operation of the hydraulic ram driving the weight into or onto the soil when no dynamic forces are acting between the ram and the weight.

9. A method for operating a soil compaction device, substantially as hereinbefore described with reference to the accompanying drawings.