A known way of compacting concrete is to plunge into it the end of a needle maintained in vibration. Compacting devices operating in this way fall into two main classes according to the sort of vibration communicated in the needle.

(1) In the first class, vibration of the needle is caused by the vibrator (which may be of known type, for example a form vibrator) fixed to the end of the needle protruding from the concrete. The vibrator imparts a rapid oscillatory motion on the point to which it is fixed; and the amplitude of the movement transmitted to different points in the concrete is greater or less according to the mass of the needle handle, according the flexibility of the needle, and according to the depth of penetration of the needle into the concrete. The concrete is compacted more or less satisfactorily but somewhat irregularly.

(2) In the second class, vibration of the needle is caused by an eccentric mass rotating within the needle itself around the longitudinal axis of the needle. As a rule good results are obtained with such a needle because the amplitude of the vibrations transmitted to the concrete is sensibly constant throughout the length of the needle.

But such a needle cannot be used to compact concrete when the concrete is formed in layers (whether vertical or horizontal) of less than 50 mm. thickness, as is the case, notably, in the narrow joints of masonry, and in reinforced concrete with closely spaced reinforcements.

The present invention enables better results to be achieved in all cases than with known devices of the first class; at least as good results are obtained as with known devices of the second class in thicknesses of concrete greater than 46 mm. and also very good results are obtained in lesser thicknesses.

According to the invention these results are obtained by the use of a needle of non-circular section to which is given an alternating movement of rotation, that is to say an oscillation around its longitudinal axis.

In order that all points on the needle may impress equal movement of the designed magnitude upon the concrete in contact with the needle, whatever the distance of these points from the axis of oscillation, the section of the needle by a plane at right angles to the axis of oscillation may with advantage be given the form of a portion of the curve described in polar co-ordinates by the equation

$$
\theta = \frac{\sqrt{r^2 - r_0^2}}{r_0^2} \text{ and } \theta = \frac{\sqrt{r^2 - r_0^2}}{r_0^2}
$$

where

The origin O is at the centre of oscillation, the radius vector r makes an angle \( \theta \) with the axis of co-ordinates Oz.

\( r_0 \) is the shortest vector at which the oscillation gives the desired displacement to the concrete.

Any means may be employed to impart oscillation to the needle.

Generally speaking the needle will be subjected to an alternating couple about its longitudinal axis.

Preferably the needle is made fast to a part subjected to the action of forces alternating in sense, the directions of which lie both in a plane perpendicular to the longitudinal axis of the needle and in planes sensibly parallel to the axis and symmetrical with respect to it, so that they transmit to the needle a torque alternating in sense.

In a first construction, two shafts turn at the same speed but in opposite directions carry eccentric masses which when they are in the plane containing the shafts and the longitudinal axis of the needle are symmetrical with respect to the longitudinal axis of the needle.

These shafts may be parallel to the longitudinal axis of the needle or they may be co-axial and at right angles to it and carry masses at each of their extremities, the masses on the ends next to the longitudinal axis of the needle being displaced by 180° from the masses at the ends distant from the axis.

In a second construction according to the invention the needle is made fast to a member in which are two cylinders containing double-acting pistons operated by fluid pressure, the axes of the cylinders being at right angles to the longitudinal axis of the needle and symmetrical with respect to it, the pressure fluid driving the pistons in opposite senses so that the forces produced by their simultaneous displacements produce a couple the axis of which is that of the needle.

By way of example there are shown in the accompanying drawings:

In Figure 1 part of the curve above described as the preferred form of the section of the needle,

In Figures 2 to 5 four cross-sections of needles are shown according to the present invention; each cross-section in each figure is shown in two positions, one position is shown in full lines and the other position is shown in dotted lines;

In Figure 6 a view of one construction of the invention partly in section,

In Figure 7 a section on the line VII—VII of Figure 6,

In Figure 8 a section of part of a second construction of the invention;

In Figure 9 a view from above of the construction shown in Figure 8 the top of the casing being removed,

In Figure 10 another construction of the invention;
In Figure 11 a section on the line XI—XI of Figure 10. The curve shown in full lines in Figure 1 agrees with the equation above given. The curve shown in dotted lines represents the curve shown in full lines after rotation through an angle 

\[
\theta
\]

and is a curve parallel to the latter and distant \( \theta \) from it.

Figures 2–5 illustrate various cross-sections of the needle which is a feature of the invention. The non-circular sections of Figures 2–5 are oscillated about the longitudinal axis of the needle, and these sections correspond to the form of the foregoing equation to describe the curve, the foregoing equation expressed in polar coordinates. Each of the cross-sections illustrated in Figures 2–5 indicate two positions for these cross-sections; one of these positions being shown in a full line, the other in dotted line.

In the device shown in Figures 6 and 7 a motor 21 drives through a flexible transmission 22 a shaft 23 on which is secured a bevel pinion 24. The bevel pinion 24 drives through similar pinions 25 and 26 two shafts 27 and 28 to which it transmits rapid movements of rotation of the same speed and of opposite sense.

Upon the shaft 27 are securely fastened two equal masses 29 and 30 arranged symmetrically with respect to a point on the shaft 27 equidistant from the point at which the masses 29 and 28 are fixed. Shafts 28 and its masses 31 and 32 are identical with the shaft 27 and its masses 29 and 30. At the beginning of the movement the four masses are in the plane containing the longitudinal axis of the needle and the axes of the shafts 27 and 28 the masses 30 and 31 being on the side of the shafts towards the needle point, and the masses 29 and 32 on the side towards the flexible transmission. The shafts 23, 27 and 28, the bevel pinions 24, 25 and 26 and the masses 29, 30, 31 and 32 are enclosed in a casing 33 in which are bearing for the three shafts.

Upon this casing are mounted a handle 34 and a needle 35 co-axial with the handle and of convenient shape, for instance of the section shown in Figure 6; this needle is to be plunged into the concrete.

In consequence of their rapid rotation the masses 29 and 32, when they are in the position shown in Figure 7, create by their centrifugal forces a couple of which the axis is \( x - x' \), while the masses 30 and 31 create a much smaller opposite couple, so that there is a resultant tending to turn the casing about the axis \( x - x' \). When the masses are in the position shown in Figure 6 their centrifugal forces produce no couple about the axis \( x - x' \).

So on each revolution of the shafts 27 and 28 the casing makes an oscillation about the axis \( x - x' \) carrying with it the needle 35 which is secured thereto.

The needle 35 is made, as indicated in Figure 5, of a light metal casting comprising curved elements of the form above described, so designed that the displacement of the needle surface in contact with the concrete has nearly everywhere the desired value.

In the construction shown in Figures 8 and 9 the shafts 36 and 37, instead of being at right angles to the longitudinal axis \( x - x' \) of the needle 35 are parallel to it and each carries two masses 38. These are eccentric to the shafts 36 and 37 and are so placed that when they are in the plane containing the shafts 36 and 37 and the axis \( x - x' \) they are symmetrical with respect to the axis \( x - x' \). Motion is transmitted to the shaft 34 from an exterior source of movement as in Figure 6 and on shaft 34 is keyed a pinion 39 engaging with identical pinions 40 and 41 keyed upon the respective shafts 36 and 37. The whole construction is arranged in a casing 42 like that shown in Figure 6 and to this casing is secured the needle 35 in manner analogous to that described below in connection with Figure 10.

The working of this arrangement is substantially analogous to that of the construction shown in Figures 6 and 7.

In the construction shown in Figures 10 and 11 the needle 35, of such a shape as has been mentioned above, is secured to a socket 51 of a truncated pyramid form which fits upon a boss 52 of similar polygonal section, and is firmly pressed upon the boss by two screws 53 and 54. The boss 52 is part of a casing 55 secured to a hollow handle 56 to which is joined a flexible compressed air conduit 57.

In the casing 55 are formed two cylinders 58 and 59 in which move heavy pistons 61 and 62. The cylinders lie in a plane perpendicular to the longitudinal axis \( x - x' \) of the needle 35, and are symmetrical with respect to that axis. The pistons 61 and 62 are moved by compressed air supplied through the conduit 57 and a passage 63.

In Fig. 11, pistons 61 and 62 located in cylinders 58 and 59 respectively are reciprocatingly moved by compressed air admitted through passage or groove 64 in cylinder 59, upper passage or groove 65 in casing 55, passage or groove 67 and conduit or passage 66 to enter chamber 68. Compressed air is likewise admitted via passage or conduit 66 in piston 61 into chamber 70. Air in the upper part of chamber 70 is vented through port 71a. Also, passages 76 in chamber 68 and lower passage 77 in casing 55 at times communicates with passage or groove 74 in cylinder 59 and with passage 75 and port 71a. Passage or groove 70 in cylinder 59 corresponds to passage 74 in cylinder 68.

When one of the pistons 61 and 62 is moving in the direction indicated by the arrow the other is moving in the opposite direction. The blade 35 is therefore subjected to a alternating movement around its longitudinal axis.

The simultaneous movement of the pistons 61 and 62 may be obtained, for example, by making the piston 61 serve as a slide valve controlling the supply of compressed air to and its exhaust from the cylinder 59.

In the construction illustrated, when it is in the position shown in Figure 11, air supplied by the conduit 63 is led through the groove 64 through the passageway 65 in piston 61 both to the conduit 66 in piston 61 and to the groove 67 and conduit 68 of piston 62, and so to the chambers 69 and 70 in cylinders 58 and 59.

With the pistons in the position shown in Fig. 11 pressure air is admitted via passages 64, 65, 66 and 68 to chamber 69 and also via passage 66 to chamber 71. Pistons 61 and 62 now move to their opposite positions, air in the upper part of chamber 70 venting via port 71a and the air in the lower part of chamber 68 via passes 76, lower passage 77 in casing 55, passages 74 and 75 and port 71a.

On reverse operation pressure is admitted to passages 63, 74, lower passage 77 in casing 55, passages 76 and 77 to the lower part of chamber
After a rotation through an angle $\alpha$ about $O$, the point $A_0$ arrives at $A_1$ upon the curve $C_1$. Drop from $A_1$ a perpendicular $A_1B$ upon the tangent $A_1B$ to the curve $C_0$ at the point $A_0$. The angle $\alpha$ being small, the length $A_1B$ represents by the second order almost the distance of a point from the curve $(C_1)$ to the curve $(C_0)$.

Let us represent the length $A_1B$ by $X$. We have:

$$X = A_0A_1 \cos \beta = r_0 \cos \beta$$

where $\beta$ designates the angle $A_0A_1B$.

Let us now determine the angle $\beta$ by calculus from the curve $C_0$ about the point $A_0$.

An increment $\Delta \theta$ of the angle $\theta$ corresponds to an increment $\Delta r$ of the radius vector.

In the right angular triangle $A_0CD$ we have:

$$CD = \Delta r$$

$$A_0C = r_0 \Delta \theta$$

$$tg \, CD A_0 = \frac{A_0C}{CD} = \frac{r_0 \Delta \theta}{\Delta r}$$

and at the limit when $\Delta \theta$ approaches 0,

$$\frac{\Delta \theta}{\Delta r} \rightarrow \frac{d \theta}{dr}$$

On the other hand, the angles $CDA_0$ and $\beta$ are equal as they have their sides respectively perpendicular so that:

$$tg \, \beta = \frac{r_0 d \theta}{dr}$$

From Equations 1 and 2 we can derive with

$$\cos \beta = \frac{1}{\sqrt{1 + (\frac{r_0 d \theta}{dr})^2}}$$

Let us reckon $r_0 d \theta/dr$ starting from the equation of the curve $C_0$:

$$\theta = (\frac{r^2}{r_0^2} - 1)^{\frac{1}{2}} - \arctg (\frac{r^2}{r_0^2} - 1)^{\frac{1}{2}}$$

Let us set:

$$x = (\frac{r^2}{r_0^2} - 1)^{\frac{1}{2}} : y = \frac{r^2}{r_0^2} - 1$$

We have:

$$\frac{dy}{dx} = \frac{2r}{r_0^2} \quad \frac{dx}{dy} = 1 - \frac{1}{2y^{\frac{1}{2}}}$$
and 
\[ \frac{dx}{dy} = \frac{1}{\sqrt{r^2 - 1}} \]
which is possible if \( r^2 / r_0^2 > 1 \) that is: 
\[ r > r_0 \]

One has also 
\[ \theta = \pi - \arctan \frac{x}{y} \]
and 
\[ \frac{d\theta}{d\tau} = 1 - \frac{2}{1 + \frac{r^2}{r_0^2}} = \frac{1 - \frac{r^2}{r_0^2}}{1 + \frac{r^2}{r_0^2}} \]

One has therefore: 
\[ \frac{ds}{d\tau} = \frac{dy}{d\tau} = \frac{2r}{\sqrt{r^2 - r_0^2}} \]

Transfer this value into Equation 3 above: 
\[ X = \frac{1}{\sqrt{1 + \frac{r^2}{r_0^2} - 1}} \]
from which \( X = r_0 \) upon the evident condition as has been set forth above that \( r > r_0 \) and this regardless of what may be the value of \( r \), which was to be shown.

 Naturally the invention is not limited to the examples described.

 Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:

1. Apparatus for tamping concrete and analogous material comprising a needle introduced into the mass to be tamped, a vibrator comprising two cylinders whose axes are parallel to one another and perpendicular to the longitudinal axis of said needle and symmetrical with relation to said longitudinal axis, two pistons located in said cylinders, fluid operated means for operating said pistons in opposite directions, a body fixed to said cylinders and said needle and transmitting the vibrations of the vibrator to said needle.

2. An apparatus as set forth in claim 1 in which one of said pistons serves as a distribution slide valve for said fluid operated means for the other piston.

3. An apparatus as set forth in claim 1 in which the section of said needle through a plane perpendicular to its longitudinal axis is constituted at least in part of portions of a curvature described in polar coordinates by the equation
\[ \theta = \left[ \frac{1}{\sqrt{r^2 - 1}} - \arctan \frac{x}{y} \right] \]

where the origin \( O \) of the co-ordinates is at the longitudinal axis of the needle, the radius vector \( r \) makes an angle \( \theta \) with the axis of co-ordinates \( O\alpha \) and \( r_0 \) is the shortest radius vector at which alternating rotation gives the described displacement of the concrete.

4. In a tool for compacting concrete or like materials, a needle insertable in the mass to be compacted, said needle having a cross section formed at least in part of portions of the curve described in polar co-ordinates by the equation
\[ \theta = \left[ \frac{1}{\sqrt{r^2 - 1}} - \arctan \frac{x}{y} \right] \]

where the origin \( O \) of the co-ordinates is at the longitudinal axis of the needle, the radius vector \( r \) makes an angle \( \theta \) with the axis of co-ordinates \( O\alpha \) and \( r_0 \) is the shortest radius vector at which alternating rotation gives the described displacement of the concrete.

BERNARD PIERRE.

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