July 17, 1956 A. W. GARDNER 2,754,734

SEGMENTED ROLLS

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Fig. 1.

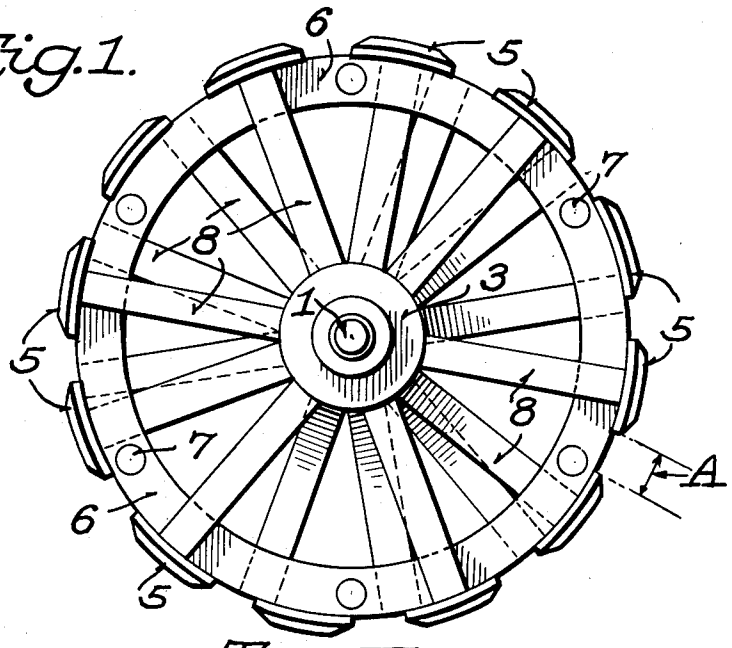
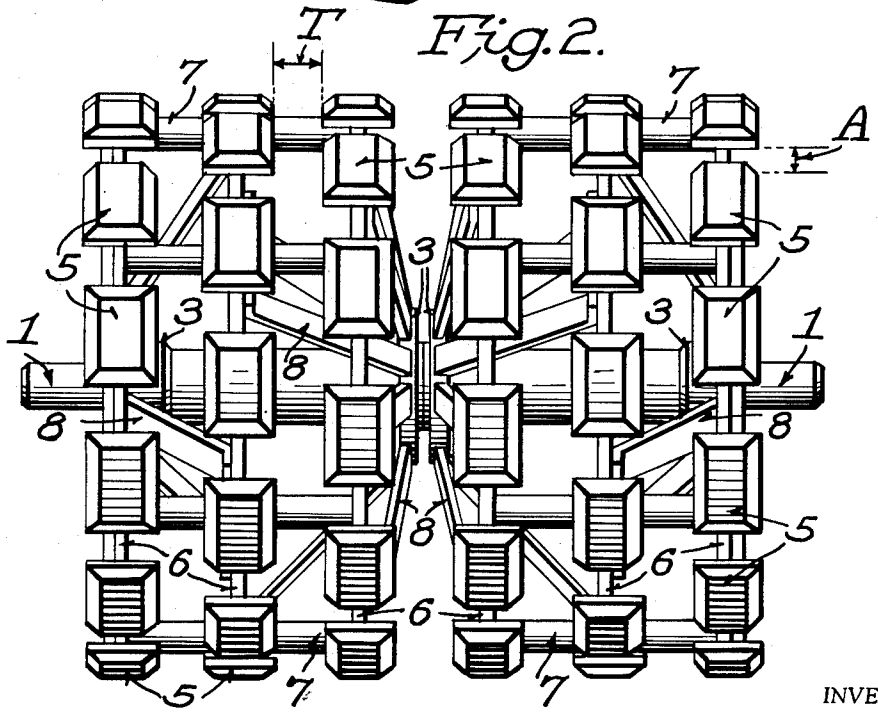


Fig. 2.



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SEGMENTED ROLLS

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Fig. 3.

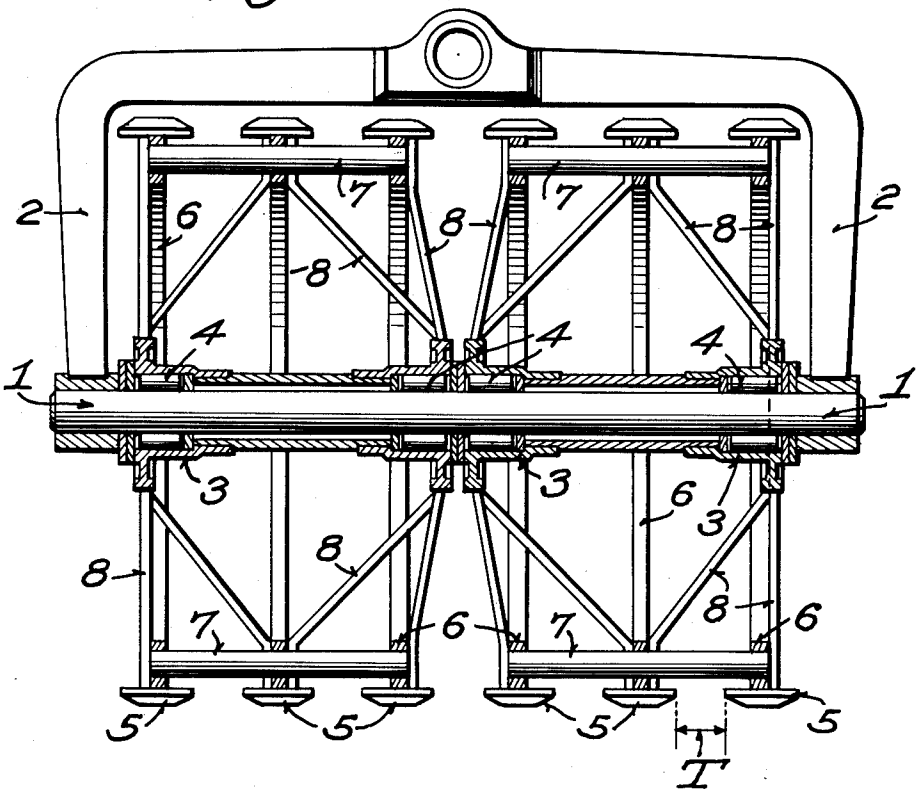
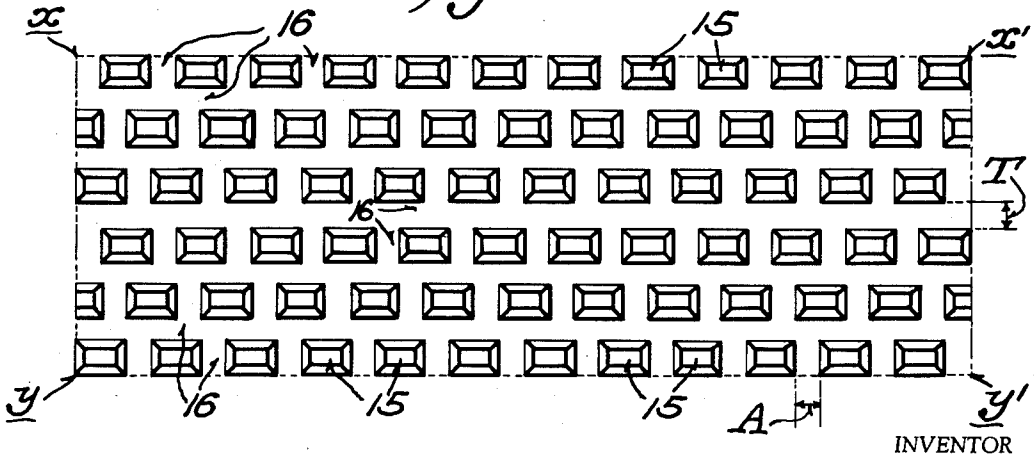


Fig. 4.



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SEGMENTED ROLLS

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Fig. 5.

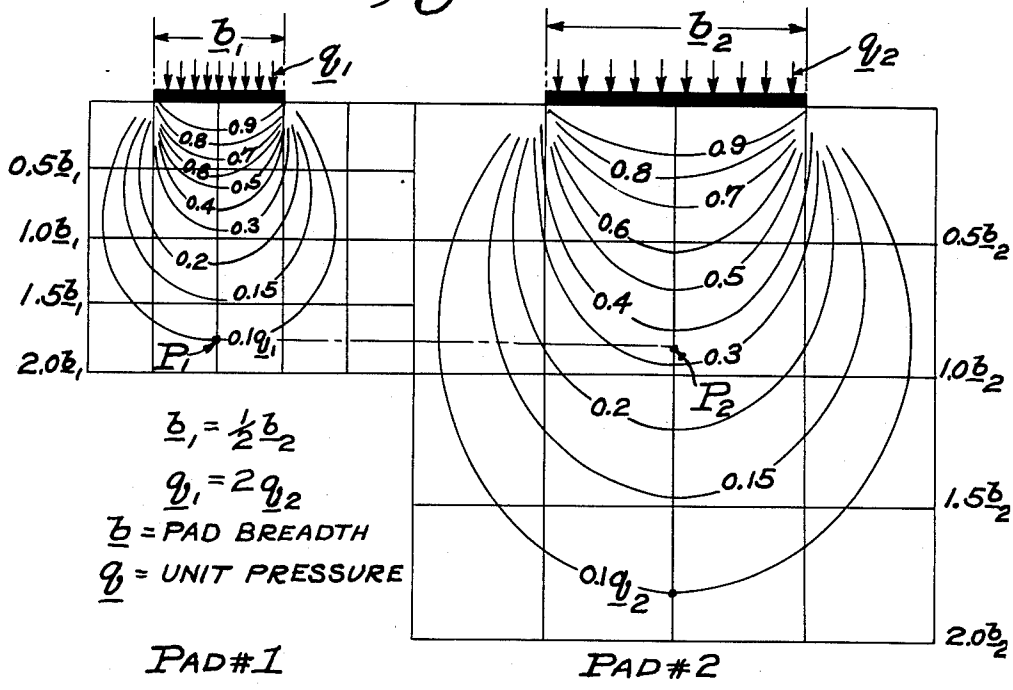
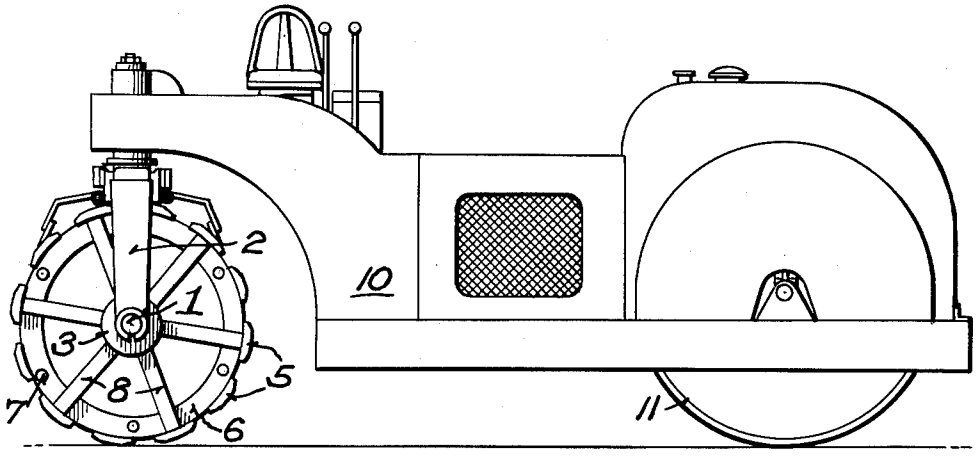


Fig. 6.



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Fig. 7.

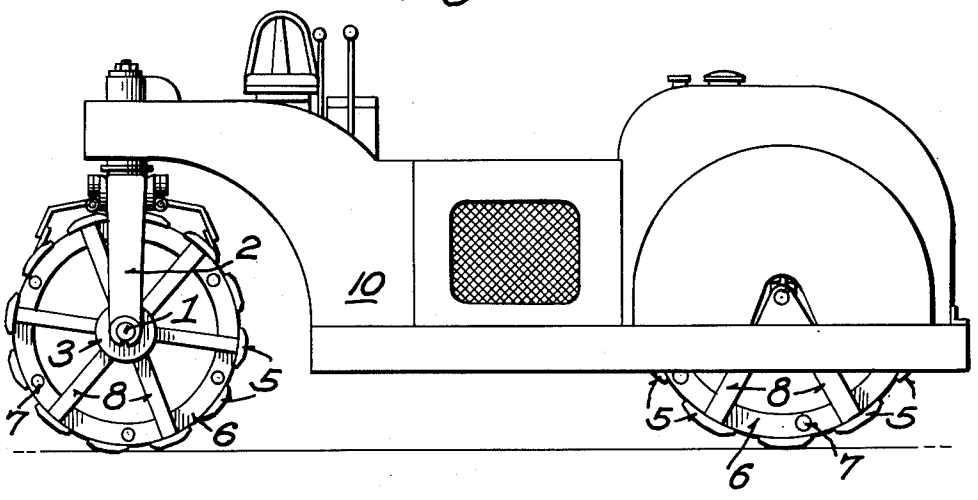


Fig. 9.

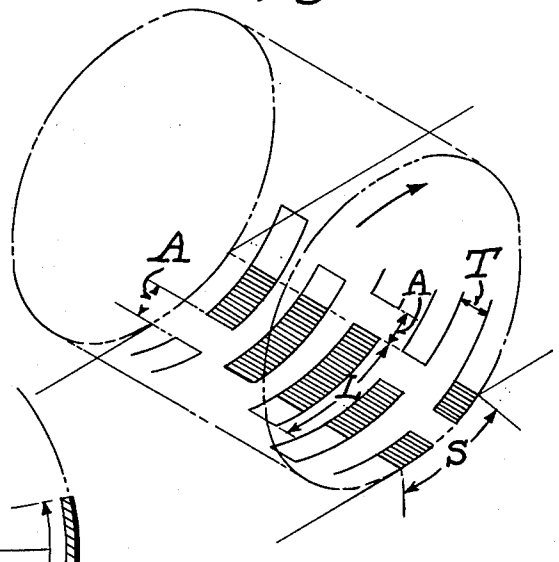
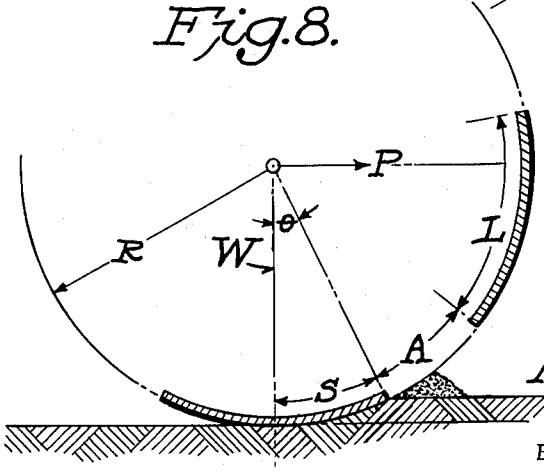


Fig. 8.



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United States Patent Office 2,754,734 Patented July 17, 1956

2,754,734

SEGMENTED ROLLS

Adryl W. Gardner, Redlands, Calif.

Application January 5, 1953, Serial No. 329,666

8 Claims. (Cl. 94—50)

This invention is a novel roll for compacting loose materials, the roll in effect comprising a cylinder whose surface is partially cut away in a certain pattern so as to leave portions of the original cylindrical surface, these portions being in the form of individual compaction pads. This novel roll obviates certain disadvantages inherent in the conventional cylindrical roll and certain other disadvantages inherent in the so-called "sheepsfoot" roll. The present application is a continuation-in-part of my copending application Serial No. 168,959, filed June 19, 1950.

It is well known that the conventional cylinder when operated as a compaction roll has a high degree of "buoyancy" with respect to the material upon which it is rolling, since its surface contact is relatively large. This surface contact includes an area under the roll equal to the width thereof times the length of the peripheral arc of contact of the roll with the material. However, the continuity of contact of the cylinder across the whole width of the roll gives rise to a serious practical disadvantage, i. e. as the roll travels along, it builds up a moving wave or wedge of loose material just ahead of its path. This wedge is pushed ahead of the roll and constantly increases in size until one of several undesirable conditions results. The wedge may become so large that the machine is stalled, or the roll may manage to climb over the wedge and leave behind a large, poorly-packed defect. This climbing effect occurs rather regularly and not only leaves a series of defects which must be specially corrected but, in addition, redistributes the materials to various uneven depths causing undesirable alternate thick and thin areas. Obviously, if the machine must climb over such a wedge every few yards, it must have a reserve of horse-power not used during the regular rolling function but necessary to climb such defects. Therefore, the horse-power of the prime mover of the machine must be chosen in a wasteful manner to provide for these surge requirements. Moreover, some of the wedge material escapes at the outer edges of the cylinder and leaves longitudinal ridges along each end of the roll.

It is, therefore, one of the principal objects of this invention to obviate this transverse-wedge and longitudinal-ridge creating tendency with a minimum impairment of the buoyancy of the roll. These undesirable effects may be eliminated by providing transversely disposed gaps across the face of the roll at regular intervals so that the material in the wedge is by-passed and left behind in small quantities which may be easily rolled flat on subsequent passes, the quantities being so small as to be negligible instead of being allowed to build up to objectionable size.

However, if the transversely disposed gaps were to be extended the full width of the roll, the total instantaneous roll area pressed against the contact surface of the material would vary as the gaps passed the material. This effect would result in non-uniform buoyancy of the roll and therefore non-uniform material compaction.

In order to correct this undesirable non-uniformity, this invention provides for the division of the roll into annular rows of compaction pads wherein the gaps of adjacent rows are staggered. With these gaps correctly located, the total pad area pressing against the arc of contact with the material, when totaled across the width of the roll, will remain constant as the roll progresses during any particular pass and therefore the weight of the roll will be supported by the same number of square inches of pad area in contact with the material to be compacted. Thus all of the material encountered by the pads is compacted to the same degree since the unit force acting on each unit area is a constant as the roll rotates over the material. Such a roll has constant buoyancy and can therefore create a smooth finished surface after successive passes. Accordingly, it is a very important object of my invention to provide a roll having a constant buoyancy as it passes over the material being compacted.

My roll, therefore, has the advantage of a true-cylinder roll (i. e. constant buoyancy), but obviates the disadvantage of a cylindrical roll (i. e. the disadvantage of building up a wedge or ridge of loose material resulting in a lumpy finished surface, or in stalling).

As opposed to the cylindrical roll, the sheepsfoot roll is not a surface-finishing roller, and is therefore only of advantage in the early stages of compaction since it would have a destructive tendency if used on a finished surface. Its principal advantage over the solid-cylinder roll lies in its greater unit-area compaction pressure. However, in acquiring this advantage it suffers several very serious disadvantages which limit its usefulness to the earlier processing stages.

Basically, the difference between the smooth-faced roll and the sheepsfoot roll is founded on the concept of buoyancy. Since the cylinder is a buoyant roll, it compacts the material from the top down; that is, on successive passes the material is pressed downwardly to progressively approach the ultimate level of the finished surface. As opposed to the cylindrical roll, the sheepsfoot roll is non-buoyant because its area of contact with the material is relatively very small and is not a constant as it rotates thereon. It compacts the material from below the ultimate finish level up toward it, that is, the individual lugs on the sheepsfoot "punch" through the material instead of rolling on top of it. The result of this characteristic is that it cannot be used for finish work since it is inherently non-buoyant and, in addition, has a strong tendency to cause "fluffing" or loosening of the surface material and partial destruction of the surface being compacted.

Thus, the sheepsfoot roll, although capable of improving an uncompacted mass of material, is also capable of destroying an already compacted surface. It is, therefore, an important object of my segmented roll to avoid the destructive tendency of the sheepsfoot roll while retaining a portion of the advanatge thereof. That is, my roll provides increased unit-area pressure while at the same time retaining buoyancy.

Moreover, because of the above destructive tendency, the sheepsfoot roll does not lend itself to the forming of an efficient compatible tandem combination when mounted on a machine with a smooth-faced cylindrical roll since the sheepsfoot roll would tend to destroy the finishing effect of the cylindrical roll. It is accordingly a very important object of my invention to provide a roll of the buoyant type which can be used in a compatible tandem combination with a cylindrical roll to provide a rolling machine of very versatile character, one which is efficient not only in the beginning stage of compaction but also in the finishing stages of surface rolling.

Another important object of my invention is to provide a buoyant type roll wherein the pads of the respec-

tive rows are staggered in such a way that the leading and trailing edges of the pads in contact with the material are not at all in alignment. This is, the transverse edges of the pads in one row lie opposite central portions of the pads in another row. An example of the type of structure to be avoided is shown in Patent #243,463, June 28, 1881, to Schaeffer. In Figs. 2 and 3 of this patent, the leading edges of the pads in one row are axially aligned with the trailing edges of the pads in the adjacent row so that the aligned transverse shearing edges of the pads on which the roll is resting all contact the material at the same instant. Thus the pads contact the material alternately instead of successively. Such a structure tends to be non-buoyant since the material will shear forwardly of the leading edge of one pad and rearwardly of the trailing edge of the adjacent pad, thereby permitting the pads to sink deeper into the material in this position than they would sink in a position wherein the roll was supported on central portions of the pads. In the above patent such alignment of the pad edges makes no difference since Schaeffer was concerned only with traction and not with providing an efficient surface finishing roll.

Still another object of my invention is to provide a roll capable of much heavier loading than has heretofore been attempted. For example, in building air fields, it is becoming increasingly difficult to roll the landing strips to sufficient load-bearing capacity for the enormous weight of the aircraft. The solid cylinder roll when loaded heavily enough to do the jab can not be moved with any reasonable amount of power. Moreover, as soon as it built up a wedge ahead of it, it would be stalled. Conversely, the sheepsfoot roll, if loaded sufficiently heavily, would simply sink to its hub. My segmented roll, however, builds up no wedge ahead of it and therefore will not stall. Moreover, the pads have enough area so that they can "float" on the material under them and continue the processing thereof until a really high load-bearing capacity surface is produced. In addition, since my roll is not destructive of finished surfaces, it can be used efficiently from the initial to the final stages of compaction.

Other objects and advantages of my invention will become apparent during the following discussion of the accompanying drawings, wherein:

Figure 1 is an end elevation of my segmented roll assembly showing the arrangement of one row of pads.

Fig. 2 is a front elevation of the roll shown in Fig. 1.

Fig. 3 is a lateral section through a composite steering roll showing the latter divided into independent right and left sections to facilitate steering; and showing a complete roll construction including hub, axle, bearings, spokes, rings, and pads—all carried on a conventional steering yoke.

Fig. 4 shows the compacting pattern left in material being processed by the roll shown in Fig. 3, the pattern representing one revolution thereof.

Fig. 5 is a schematic representation in a vertical, axially disposed place showing lines of constant compaction stress below two pads, the left pad being half the width of the right pad but loaded to the same total weight.

Fig. 6 is a side elevation of a tandem rolling machine wherein the segmented roll as shown in Fig. 3 is mounted as a guide roll in compatible combination with a conventional cylindrical drive roll.

Fig. 7 is a side elevation of a tandem rolling machine similar to Fig. 6, but said machine having a segmented roll on both axles.

Fig. 8 is a schematic representation in a plane normal to the axis of the roll showing the dimension of the pads in a row, the spacing therebetween and the forces acting on the roll.

Fig. 9 is a schematic representation in perspective showing the dimensions and spacings of the pads on a roll having five rows thereof.

In the practical embodiment shown in the drawings, Figs. 1, 2 and 3, the segmented roll is journaled on an axle **1** which may be supported at its outer ends by a steering yoke **2** if the roll is used on a machine as a guide roll, though it may also be used as a drive roll, Fig. 7. The hubs **3** are journaled in bearings **4** on the axle **1** and carry the supporting members for the compaction pads **5**. In the embodiment herein illustrated, the pads **5** are fixed around axially spaced annular rings **6** maintained in proper separation by spacers **7**. The rings **6** may be supported by a plurality of spokes **8** radiating from the hubs **3**, and additional strength may be provided by a disposing some of the spokes at an acute angle with respect to the axle **1**.

This assembly for mounting the compaction pads **5** may be varied in any expedient manner so long as the pads **5** are rigidly supported in their intended positions. In a guide roll assembly as shown in Fig. 3, the roll may be divided into independently journaled halves, but in a drive roll, such division would probably not be of advantage.

One important feature of any pad mounting assembly, however, is that it should provide an open-work structure which will not collect and retain quantities of the material being processed, otherwise such material might pack solidly into the pad interstices and cause the segmented roll to take on the characteristics of a conventional roll to take on the characteristics of a conventional cylinder, which result would be highly undesirable. In the present assembly the open spaces between the pads are not blocked from the inside and therefore any material tending to pack therein will be pushed through the outer periphery of the roll instead of being packed solidly into the interstices.

Fig. 6 shows the roll and yoke assembly of Fig. 3 mounted as the guide roll of a conventional two-axle tandem machine **10**, the drive roll **11** of which may be a conventional cylindrical roll. By reference to the ground pattern of the segmented roll, shown in Fig. 4, it may be seen that on the first pass of the segmented roll, a series of waffle-like depressions **15** are made by the pads **5**, the distance from x—y to x'—y' representing the ground pattern created by one revolution of the roll. After such a pattern has been created by the segmented roll, the material at the interstices **16** will, of course, project above the compacted material **15** so that as the smooth-faced roll **11** follows the path of the segmented roll, the roll **11** will pass over the raised material **16** and compact it substantially to the level of the material **15**. It is very important to note when compacting with a tandem combination of this type that until the material **16** is compacted level with the material **15**, by the smooth-faced roll **11**, the roll **11** will act like a segmented roll whose surface is cut away in a pattern complementary to the leading segmented roll on the machine, since the raised material **16** initially supports the roll **11** at it passes thereover. Once the material **16** is level with the material **15**, however, the roll **11** will assume again the compaction characteristics of a smooth-faced roll, and will accordingly leave behind it a smoothed surface. Because of the fact that the segmented roll does not build up a traveling wedge of loose material ahead of it, a machine equipped with a leading roll of this type may be used to process material so loosely packed that it would stall the machine if its leading roll were a conventional cylinder. Accordingly, the segmented roll may be loaded sufficiently heavily to highly compact the material **15** under the pads **5** without stalling, and the cylindrical roll **11**, if more heavily loaded than the segmented roll, will subsequently not only compact the material **16** to the same level as the material **15** but will also deliver a final stressing to both materials **15** and **16**, thus resulting in a relatively smooth surface after each pass of the machine.

Moreover, compatible tandem combinations are not

limited to two-axle machines. Three-axle tandem machines may be fitted with one or more of the segmented rolls to replace the conventional cylindrical rolls generally used thereon. Also where it is necessary to roll very loosely packed material or to roll harder packed material to extremely high density, a tandem roller employing a segmented roll on each axle would prove to be highly effective, this combination being illustrated in Fig. 7.

Thus far, this disclosure has been directed toward the general characteristics and advantages of the segmented roll per se and of the combinations thereof in tandem rolling machines, without particular emphasis on the size of the pads or the spacing therebetween.

The characteristics of the segmented roll may be explained by reference to a concept designated as the "pressure bulb" in Taylor's "Fundamentals of Soil Mechanics," page 567 (John Wiley & Sons, 1948), and illustrated in the present drawings, Fig. 5. The following discussion is intended to be taken only in a qualitative sense and is offered only for the purpose of showing that other factors being the same, an increase in pad area brings with it an increase in the effective depth of compaction of the soil therebelow. The following example illustrates the effect of merely doubling the width of the pads on a particular segmented roll without changing the total weight supported by the roll, and without change in the other variable factors.

Fig. 5 shows two pressure bulbs, one twice as large as the other, but otherwise identical. At the top of each bulb is the cross section of a compaction pad, the two pads in this figure representing the pads on two different compaction rolls, which pads are assumed to be of the same annular length. However, pad #1 is only half as wide as pad #2. In order to provide a clear analogy, it is assumed that each pad supports the same total weight so that the pressure q per unit area is twice as great under pad #1 as under pad #2. The plane of these pressure bulbs is vertical and includes the axis of the rolls. The bulb-shaped lines are lines of constant stress in the material caused by loading of the material by the pads pressing downwardly thereon. The unit area pressures are expressed in terms of the magnitudes of q_1 and q_2. If an arbitrary point P_1 is chosen below pad #1 and a point P_2 of the same depth is chosen below pad #2, it will be apparent that the stress at P_2 is $.35q_2$, and that the stress at P_1 is $.1q_1$. As stated above, $q_1=2q_2$ and therefore, by simple substitution, it is apparent that the radio of stresses at the chosen depth below the respective pads is:

$$\frac{P_1}{P_2}=\frac{.1q_1}{.35q_2}=\frac{.1+2q_2}{.35q_2}=\frac{4}{7}$$

Thus, doubling the pad width while retaining the same total weight thereon raises the compaction stress by a ratio of 7:4 at the particular depth chosen in this example.

The reason for this increase in compaction stress below the pad is easily explained in terms of the shearing motion of material being compacted therebelow. It is well known that if a very small bearing surface is used to compact loose material, in pressing the material downwardly it forces a high proportion of the material laterally outwardly instead of compacting it downwardly. Before material can be compacted it must be confined to prevent it from retreating from the compacting force by escaping it laterally. Thus where a larger bearing area is employed, the material under the center of such area is prevented from escaping laterally by the immediately adjacent material which is also stressed by the bearing area and is opposing such escape with its own laterally directed force. The result is that the material nearer the center of the bearing area can not escape and is thus subjected to the full force of compaction.

From the above it appears that two advantages accrue from making the pads **5** relatively large: (1) the material under the larger pad may be stressed to a greater depth than that under the smaller pad and (2) since the volume of material under the larger pad is greater, when unit pressures are equal more material is processed to a greater depth on a single pass of the pad than would be processed under the smaller pad.

There are, however, other factors which must be considered in determining pad dimensions and spacings. If the wedge-pushing effect of the solid cylindrical roll is to be avoided, annular gaps A must be provided between the pads in a row. Moreover, since the segmented roll can be heavily loaded without the danger of stalling inherent in the cylindrical roll, higher unit-area pressures may be used, and therefore it is useful to provide transverse gaps T between the respective rows of pads **5** to reduce the total contact area. In view of the pressure bulb discussion above, it might seem better to reduce the gaps T and increase the loading on the roll by making the machine heavier, but practical consderations dictate otherwise. In the first place, segmented rolls will be used on many presently existing machines, the weight of which is already determined. In the second place, the segmented roll will often be used in tandem combination with smooth faced rolls, and since the gaps T leave uncompacted material **16** as shown in Fig. 4, the smooth faced roll during a pass will resemble a segmented roll of complementary surface with respect to the segmented roll since the cylindrical roll compacts the raised portions **16** of the waffle-like pattern, Fig. 4, as discussed above. Therefore the gaps should be wide enough so that the pressure bulbs of adjacent pads do not unduly overlap below the surface whereby the said complementary surfaces of the smooth roll will do their share of the compaction.

The optimum pad width is thus a compromise between providing a wide pad to take maximum advantage of the pressure bulb theory above, and providing a pad narrow enough to secure sufficient unit-area loading for a given type and weight of machine, and to provide a composite roll having pads of such proportion with respect to the cut away area that such rolls may be efficiently used in tandem combinations with smooth-faced cylindrical rolls. The best compromise will vary with the character of the different materials being rolled, i. e., soil, asphalt, gravel, etc.

In the design of a particular roll the diagram shown in Fig. 8 is of assistance. In this figure, a roll of circumference C engages the ground along an arc of contact S which arc subtends an angle θ at the axis of the roll. This roll has compaction pads of length L which pads are annularly spaced by a distance A, the roll of weight W being pulled forward by a force P. The coefficient of rolling friction of the roll is

$$fr=\frac{P}{W}=\tan\theta$$

Values for fr can be found tabulated in standard handbooks for various types of materials to be compacted. The range in road construction work usually varies between about .5 for loose sand and about .1 for asphalt. In designing a roll, the largest value of fr which the roll is to encounter is chosen and also the diameter of the roll selected. In addition, the number of rows of pads, or multiples thereof, must be determined. Fig. 9 shows a 5 row roll having pads arranged for constant buoyancy, which arrangement is defined by the formula

$$L=\frac{(n-1)}{(n-2)}S$$

where N is the number of rolls, or multiples thereof. Having selected fr, S can be determined by finding the

angle θ for which fr is the tangent, and then using the formula

$$S=\frac{\theta}{360}C$$

The spacing A between the adjacent pads in a row is

$$A=\frac{L}{n-1}$$

If these formulas are used a constant buoyancy roll will result. Note that by varying the diameter of the roll and the number of rows in the roll, the arcuate pad length L can be varied.

It is usually desirable to confine L within the range of 6" to 17" in rolls used in road construction since if L goes much below 6", the roll will start punching through the material and will suffer the disadvantages of a sheepsfoot roll, i. e., insufficient buoyancy in all materials. On the other hand, if the dimension L goes much above 17" the wedge material built up by the pads is dumped, or bypassed, too infrequently and the roll will suffer the wedge-pushing disadvantage of the smooth-faced roll.

For general soil and road material compaction work the spacing between pads in adjacent rows must be chosen so as to provide pads having a width which will give a satisfactory pressure bulb profile. In addition, the transverse gaps T must be great enough to prevent undue overlapping of the adjacent profiles below the surface being rolled. For general road construction purposes, a satisfactory range of total pad area to total area of the cylinder is ⅓ to ¾, i. e., the cut away area, spacings A plus spacings T, amounts to ¼ to ⅔ of the total cylindrical area depending on the type of material to be rolled. The above ratio (⅓ to ¾) applies to rolls of diameters ranging from 36 inches to 72 inches, approximately.

Generally, in rolling non-cohesive or granular materials or in rolling thin lifts, the spacings T need not be great since the profile lines of the pressure bulb tend to extend only a short distance outwardly beyond the sides of the pads; but in rolling cohesive materials or relative thick lifts, the profile lines extend outwardly a considerable distance beyond the sides of the pads and would unduly overlap if the adjacent rows of pads were not spaced apart further than those used on granular materials or thin lifts.

During a rolling operation, the whole pad width will be in contact with the material at one time, but this is not necessarily true of the arcuate length of the pad. In rolling soft or uncompacted materials the roll will tend to sink thereinto so that a pad at the lower periphery of the roll may contact the material over its whole length. But in rolling hard or more compacted materials the length of the contact arc of the pad with the material may be shorter than the full length of the pad since the pad will sink less deeply thereinto. As a matter of fact, both conditions usually occur during the same processing operation, i. e., the arc of contact shortens with each pass of the roll.

According to Taylor's "Fundamentals of Soil Mechanics," the narrower dimension of a bearing surface controls the amount of force which can be applied to the column of material below it before shearing will result. Thus, the narrower pad dimension controls the characteristic of the present pad, at least in the earlier stages of compaction. This control by the narrower dimension results from the fact that if shearing takes place it will be transversely of the longer dimension since a long narrow bearing surface will tend to cause the material thereunder to shear transversely outwardly thereby permitting the material directly thereunder to escape the pressure. Therefore, so long as the annular arc of contact with the material is longer than the pad width, the pressure bulb will remain unchanged. On successive passes of

the roll, however, the length of the arc of contact decreases until eventually its length will equal or be less than the pad width. It should be noted here that in the case of a solid cylindrical roll, the pressure bulb shrinks on every pass thereof, since the bulb is controlled by the arc of contact rather than by the roll width, the former being the smaller dimension. In the case of the solid cylindrical roll, this decrease in bulb size is a disadvantage, but in the case of the segmented roll the decrease in the length of the arc of contact with increase in the material density is an advantage (until it decreases to the point at which it is less than the pad width) because the unit pressure of the roll increases with each pass without decrease in the depth of the pressure bulb. But any decrease below the width of the pad is a disadvantage because the profile of the pressure bulb then becomes dependent on the now-shorter length of contact dimension and therefore the pressure-bulb shrinks in size on each pass.

The arcuate-length dimension of the pads must be chosen short enough so that the latter does not build up wedges of objectionable size but leaves behind the wedge material at frequent intervals. On the other hand, since the pads must have sufficient area to prevent their sinking too deeply into the material being processed during the early stages of compaction, the pads must be long enough in comparison to their width to give the buoyancy needed.

Proper choosing of the pad dimensions and spacings will depend on the type of machine on which the roll is to be mounted and on the character and density of the material to be processed. Moreover, the pads need not be rectangular, but may be elliptical or circular, or of other polygonal form. In the drawings the pads are shown to be chamfered somewhat to relieve the tendence of the material to shear along the edges of the pads, and to reduce the tendency of the pressure bulbs of adjacent pads to overlap. This chamfer is only about 12 degrees with respect to the working surface of the pads, and in fact need not be used at all. The chamfer could also be replaced by a radius of about the same shape.

I claim:

1. A roll for compacting loose material comprising a composite cylindrical broken surface supported on a hub, said surface comprising spaced adjacent annular rows of substantially similar discrete compaction pads, the pads in each row being separated circumferentially by uniform gaps therebetween and the pads of the rows being mutually staggered, said roll including a group of at least three adjacent rows wherein no transverse line drawn across said composite surface parallel with the axis of the roll passes through more than one gap.

2. A roll as defined in claim 1, wherein the total pad area in all transverse roll sectors of equal angular extent is constant.

3. A roll as defined in claim 1, wherein the circumferential length of said gaps conforms to the formula

$$A=\frac{L}{n-1}$$

wherein A is the gap length, L is the circumferential pad length, and n is the number of rows in said group.

4. A roll as defined in claim 1, wherein the total pad area of the roll falls within the range of from ⅓ to ¾ the peripheral surface area of a solid cylindrical roll of the same dimensions as said composite roll.

5. A roll as defined in claim 1, wherein the length of each pad is greater than its width.

6. A multiple-axle rolling machine having a plurality of axle-mounted compaction rolls, at least one of said rolls comprising a composite cylindrical broken surface supported on a hub, said surface comprising spaced adjacent annular rows of substantially similar discrete compaction pads, the pads in each row being separated circumferentially by uniform gaps therebetween and the pads of the rows being mutually staggered, said roll including

a group of at least three adjacent rows wherein no transverse line drawn across said composite surface parallel with the axis of the roll passes through more than one gap.

7. A machine as defined in claim 6, wherein at least one other of said rolls is a conventional cylindrical roll.

8. A machine as defined in claim 6, wherein the total pad area in all transverse roll sectors of equal angular extent is constant.

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