

March 11, 1958

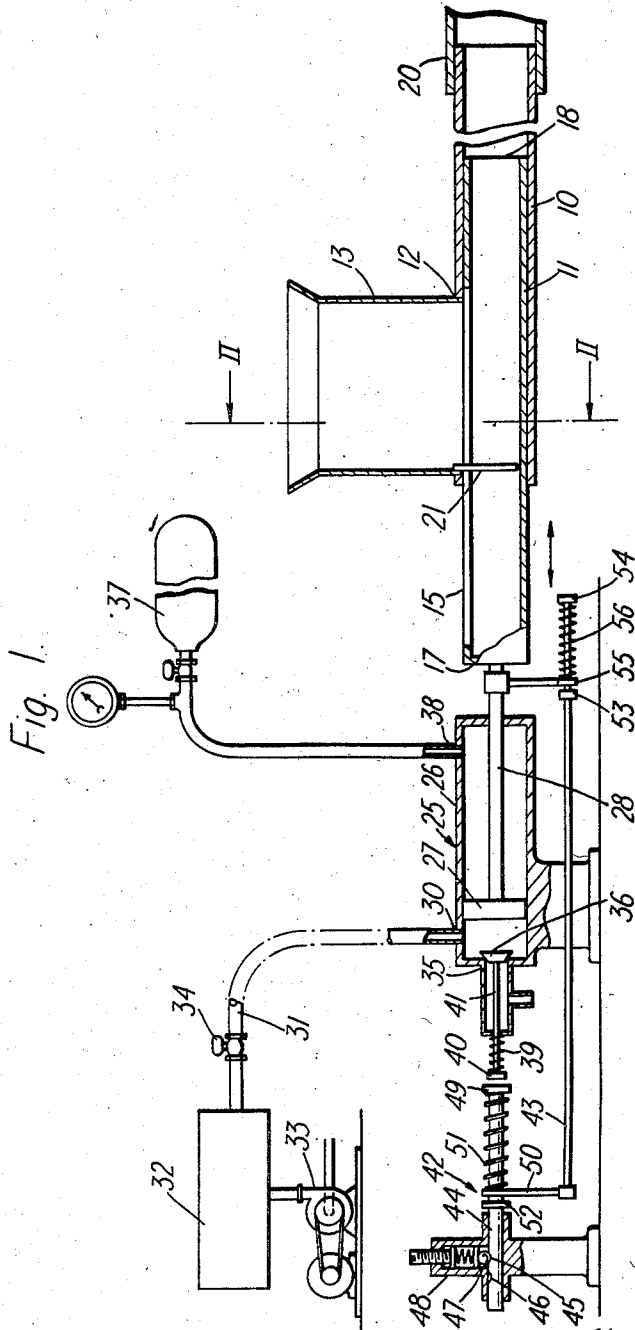
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PUMPING OF CONCRETE

Filed Jan. 17, 1955

2 Sheets-Sheet 1



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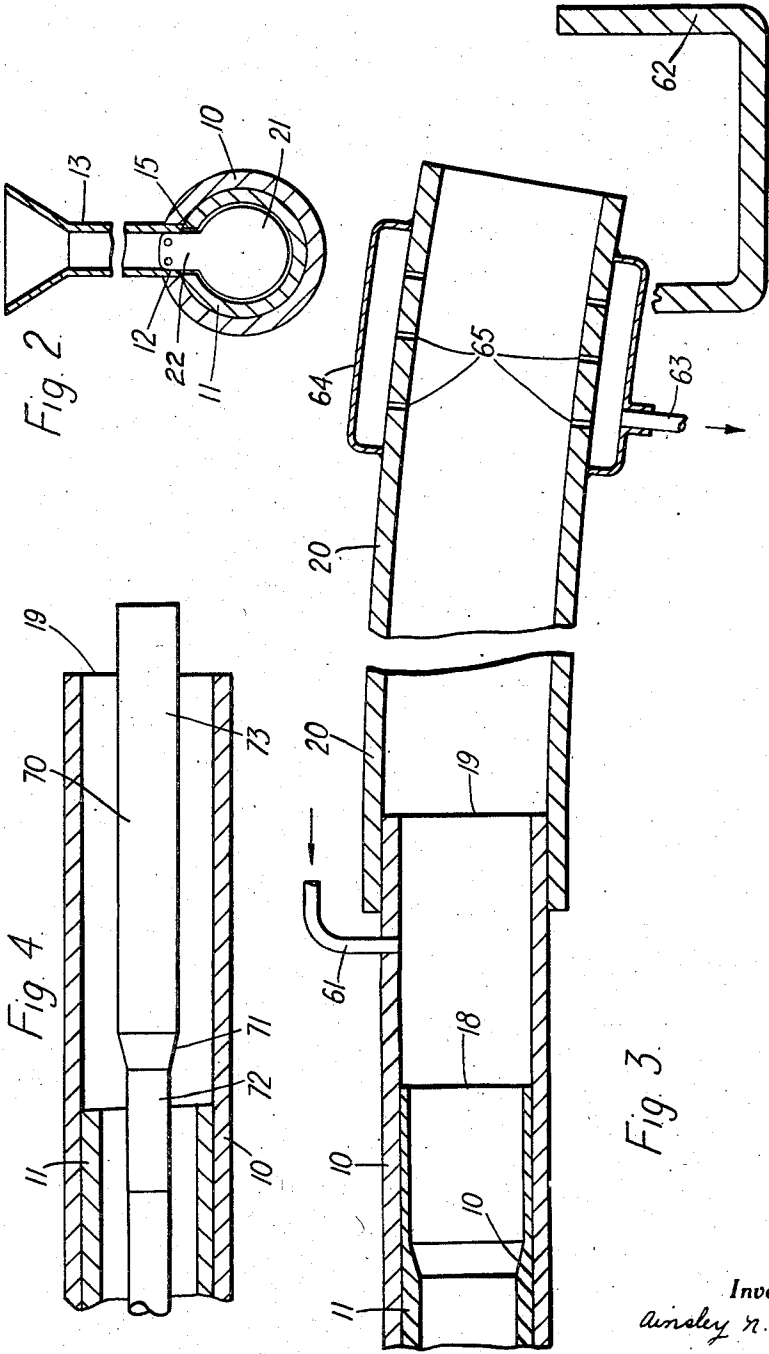


Fig. 3

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PUMPING OF CONCRETE

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Application January 17, 1955, Serial No. 482,315

Claims priority, application Great Britain
January 20, 1954

14 Claims. (Cl. 25—16)

This invention relates to the pumping of wet concrete in the plastic state, and may be applied for example to the propulsion of a continuous stream of concrete through a closed pipe, or to its consolidation under pressure in a mould, or to the forcing of the concrete through an extrusion device for the production of an extruded article. The invention is particularly though not exclusively applicable to the continuous extrusion of concrete pipes underground by means of a mole plough in combination with an extruder.

According to one aspect of the present invention, a pump for pumping a column of wet concrete in the plastic state includes a hollow tube having an inlet at or near one end and having its other end open as an outlet leading to a receiver, means for supplying the concrete to the interior of the tube via the inlet, and means for causing the tube to reciprocate in the axial direction, the linear acceleration given to the tube during its movement on its forward stroke towards the receiver being so low that there is no slip or substantially no slip between the tube and the concrete contained therein during the whole or the majority of the forward stroke, whilst during the majority of the return stroke the linear acceleration given to the tube is so great that there is slip between the wall of the tube and the concrete contained therein due to the inertia of the concrete. Thus the concrete will be progressively advanced or pumped towards the receiver through the bore of the tube.

For the purposes of the present invention the term "wet concrete" is used to include any mixture of cement and sand with gravel and/or other aggregate, containing water in any quantity up to saturation, and with or without entrained air and/or additives for producing foaming or entrained gases or for lubrication purposes.

Such wet concrete, when in the plastic state prior to the setting of the cement, exhibits two physical characteristics which are of importance to the present invention. Firstly appreciable static friction can be developed between the concrete and the walls of a container or any other tangential surface, and such friction increases with the pressure exerted by the material on the surface in the zone of friction. Secondly, the material when subjected to compressive stress in one direction is capable of exerting a corresponding though smaller stress in a transverse direction. For example if a cylindrical specimen is compressed axially it tends to expand radially unless prevented by a container which will then be subjected to radial pressure by the mixture.

These characteristics are made use of in the present invention, in which the friction between the wall of the reciprocating tube and the concrete therein during the forward stroke of the tube towards the receiver tends to produce a pressure gradient in the column of concrete

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in the tube, the pressure increasing progressively towards the outlet end of the tube. The increased pressure in turn tends to increase the friction between the concrete and the tube, so that the effect is cumulative and so that the whole column of concrete, or the bulk of it, tends to move solidly with the tube towards the receiver during this stroke.

During the return stroke however the acceleration of the tube is so rapid that the available friction cannot move the concrete column back with anything like the same acceleration due to its inertia, and slip occurs. There is thus a steady progression of the column of concrete through the tube towards the receiver, accompanied by an increased pressure adjacent the receiver.

The present invention according to another of its aspects comprises a method of pumping wet concrete by supplying wet concrete in the plastic state to the interior of a hollow tube via an inlet at one end whilst continuously causing the tube to reciprocate in the axial direction, the other end of the tube being open and leading to a receiver, in which the linear acceleration given to the tube during its forward stroke towards the receiver is so low that there is no slip or substantially no slip between the tube and the concrete contained in it during the whole or the majority of the forward stroke, whilst during the majority of the return stroke the linear acceleration given to the tube is so great that there is slip between the wall of the tube and the concrete contained therein due to the inertia of the concrete.

The receiver may be in the form of a pipe or flexible hose or the like through which the concrete is to be transmitted to the place or mould in which it is to be poured and consolidated to a required shape or section, or it may include an extrusion orifice for the extrusion of a continuous length of concrete having a particular cross-section.

The invention may very conveniently be applied to the formation of concrete pipes underground, the concrete being delivered under increased pressure from the reciprocating pump to an extruder incorporated in the mole of a mole plough, whereby a concrete pipe is continuously extruded into the tunnel produced by forcing the mole plough through the ground. The method of supplying the concrete to the extruder by means of the present invention is particularly convenient in this application, as the moving parts needed for pumping the concrete through the extruder are reduced in number and the extruding cycle can be performed at a rate controlled in accordance with the rate of advance of the mole plough. It is found that the pumping method of the present invention works particularly well using the coarse, rather dry mixes which are suitable for permeable concrete drain pipes.

In some cases it may be necessary to feed the concrete positively to the inlet end of the reciprocating tube, as by a gravity feed, with or without a vibratory action, to ensure continuity. In other cases where the mixture is such as to be able to transmit small tensile stresses, the concrete may be able to draw itself into the tube during each advancing stroke without outside assistance.

Whilst the reciprocating tube will generally be of uniform cross-section from end to end, for example of cylindrical cross-section, in some cases it may be desirable to include in the tube a length in which the walls of the tube diverge towards the outlet end, to provide a choke effect on the forward stroke of the tube. This region of divergence may be situated at the outlet or at the inlet of the tube or at some intermediate point along its length.

For the purpose of manufacturing certain extruded sections, a core or cores may be positioned inside the reciprocating tube, extending along the whole or a part of its length.

When the invention is employed for the propulsion of concrete through a pipe or hose, additional water may be introduced into the material in the hose at a point downstream from the outlet from the reciprocating tube and sufficiently spaced from it to prevent such additional water percolating back into the reciprocating tube. Such additional water will saturate or supersaturate the concrete being transmitted and will reduce resistance due to friction. The excess water may be removed at the delivery end by applying an external suction to a short length of the delivery hose which is provided with radial perforations in its wall.

The invention may be carried into practice in various ways, but certain specific embodiments will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic side elevation of a reciprocating pump for wet concrete,

Figure 2 is a cross-section on the line II—II of Figure 1,

Figure 3 is a fragmentary diagram showing a modification in which the reciprocating sleeve is choked, and,

Figure 4 is a fragmentary diagram showing another modification including an extrusion orifice.

In the embodiment illustrated in the drawings a pump for pumping wet concrete comprises a fixed tubular pump barrel 10, in the form of a plain steel tube of 2 inches internal diameter and 30 inches length, within which slides a tubular reciprocating pump sleeve 11 of slightly shorter length. The barrel 10 has a longitudinal slot 12, some 8 inches in length, formed in its upper wall adjacent one end, and a hopper 13 of generally flattened form is secured to the barrel with its lower end leading into the slot 12. The reciprocating sleeve 11 projects coaxially out of the end 14 of the barrel and is itself formed with a slot 15 some 16 inches in length which registers with the slot 12 in the barrel, so that concrete poured into the hopper 13 will be introduced under gravity into the interior of the sleeve 11 through the slots 12 and 15. The projecting end 17 of the sleeve 11 is closed whilst its other end 18, within the barrel, is open. The outlet end 19 of the barrel, remote from the hopper 13, is open and is connected through a flexible hose 20 to a suitable receiver or mould (not shown) for the pump concrete. A circular tongue 21 is mounted within the bore of the sleeve 11 by means of an integral lug 22 which extends upwardly through the slots 15 and 12 and is secured to the barrel, as shown in Figure 2, so that the tongue 21 which is a fairly close fit in the bore of the sleeve 11 divides the bore of the sleeve into two parts, namely a part within the barrel 10, to the right of the tongue as shown in Figure 1, and a part extending outwardly to the left of the tongue as shown in Figure 1, beyond the rear end 14 of the barrel and beyond the slot 12. The tongue 21 serves to prevent concrete delivered by the hopper 13 through the slot 12 from passing into the portion of the bore of the sleeve 11 which is to the left of the tongue 21 as shown in Figure 1.

The reciprocation of the sleeve 11 is produced by a combined hydraulic and pneumatic double-acting ram indicated generally at 25, the ram having a fixed cylinder 26 which is mounted coaxially with the barrel 10. The ram piston 27 is mounted on one end of a piston rod 28 whose other end is secured to the end 17 of the reciprocating sleeve 11. An inlet port 30 formed in the ram cylinder 26 is connected through a pipe 31 to a supply of hydraulic fluid maintained under pressure in a reservoir 32 of a motor-driven pump 33, and the hydraulic fluid under pressure is admitted continuously at a slow rate controllable by means of a valve 34 into the interior of the cylinder 26 on the side of its piston 27 which is

remote from the sleeve 11, so as to produce a slow and substantially uniform advancement of the piston and consequently of the sleeve during its forward or pumping stroke in the direction towards the outlet end 19 of the barrel 10. An exhaust port 35 of large area is also provided in the same end of the cylinder 26 and is normally closed by a spring-loaded poppet valve 36.

The return stroke of the sleeve 11, in the direction away from the open end 19 of the barrel 10, is effected by the action of compressed air from an air bottle 37 which is permanently connected to an inlet 38 formed in the ram cylinder 26 on the opposite side of its piston 27 from the inlet valve 30 and outlet port 35, and the action of the compressed air on the piston 27 gives a very rapid acceleration to the sleeve 11 on its return stroke when the hydraulic pressure in the other end of the cylinder is released.

The admission of hydraulic fluid through the inlet 30 into the ram piston continues throughout the return stroke of the piston, but the hydraulic pressure in the cylinder is released during the return stroke by the opening of the poppet valve 36, so as to allow the return movement of the piston under action of the compressed air supplied through the inlet 38.

The poppet valve 36 is normally held closed by a light valve spring 39 acting on a shoulder 40 formed at the end of the valve stem 41. The opening of the poppet valve 36 is effected by a spring-loaded hammer generally indicated at 42 and actuated by a connecting rod 43 driven by the sleeve 11, so that the movement of the sleeve at the end of its forward or output stroke operates the hammer 42 to open the poppet valve 36 and release the hydraulic pressure, thereby permitting the return stroke of the piston and sleeve to start under the action of the compressed air.

The hammer 42 comprises a bolt 44 formed with recesses 45 and 46 for engagement by the ball 47 of a spring-loaded ball catch 48, which permits the axial movement of the bolt 44 through a short distance between the recesses 45 and 46. In its rear position, in which the ball 47 engages the recess 45, the head 49 of the bolt is just clear of the rear end 40 of the valve stem 41, but when the bolt is moved forward until the recess 46 is engaged by the ball 47, the head 49 of the bolt will strike the rear end 40 of the poppet valve and will move it forwards to open the valve. The forward movement of the bolt 44 is triggered off by the connecting rod 43, whose end carries a yoke 50 embracing the bolt 44, and a compression spring 51 surrounds the forward part of the bolt 44 between its head 49 and the yoke 50. When the connecting rod 43 is moved forwardly by the movement of the sleeve during its output stroke towards the open end 19 of the barrel 10, the forward movement of the yoke will progressively compress the spring 51 until a point is reached at which the force of the spring acting on the head 49 of the bolt 44 overcomes the ball catch 48, and the bolt 44 flies forwardly to strike the end 40 of the poppet valve 36 and to open the valve 36. Forward movement of the bolt is limited by the engagement of the ball catch 48 with the second recess 46, so that the valve 36 remains held open. During the last part of the return stroke of the sleeve, the rearward movement of the connecting rod 43 following the sleeve is transmitted to the bolt 44 by the engagement of the yoke 50 with a flange 52 formed on the bolt, to move the bolt back into its rear or cocked position in which the ball catch 48 engages the recess 45, thereby permitting the valve 36 to close. The forward end of the connecting rod 43 carries a pair of adjustable stops 53 and 54, and a yoke 55 rigidly secured to the piston rod 28 slides along the connecting rod 43 between the stops 53 and 54 to provide a lost-motion connection between the sleeve 11 and the connecting rod 43. A light compression spring 56 is inserted between the yoke 55 and the front stop 54. Thus the adjustment of the positions of the stops 53 and 54 along

the connecting rod 43 enables the limits of the forward and return strokes of the sleeve 11 to be regulated, by determining the points at which the poppet valve 36 is opened and closed.

In the operation of the pump, during the forward stroke the sleeve 11 moves slowly towards the outlet end 19 of the barrel 10 carrying with it a column of concrete jammed in its interior, and thus forces ahead of it more concrete already in the interior of the barrel 10. During this forward movement, which is produced by the admission of hydraulic fluid to the ram cylinder 26 through the inlet 30, the leading end of the sleeve 11 filled with concrete acts as a solid piston, the concrete within it being jammed solidly by the pressure and by the resultant cumulative static friction of the concrete with the internal surface of the sleeve. As the sleeve advances, its empty portion, shown to the left of the tongue 21 of Figure 1, is progressively moved beneath the hopper 13 and is progressively filled with concrete from the hopper.

When the sleeve 11 reaches the end of its forward stroke, the precise moment of which is determined by the position of the stop 54 on the connecting rod 43, and by the strength of the compression spring 51 in relation to the setting of the ball catch 48, the hammer 42 will be released to open the poppet valve 36 thus releasing the hydraulic pressure through its exhaust, and permitting the start of the return stroke under the action of the compressed air from the bottle 37. The release of the hydraulic pressure causes the compressed air to act on the piston 27 like a hammer blow, snatching the sleeve 11 away from the outlet end 19 of the barrel, and the inertia forces acting on the concrete in the sleeve prevent the building up of jamming pressures within the sleeve so that slip occurs between the sleeve and the concrete contained within it and the latter remains more or less stationary during the return stroke of the sleeve. The newly supplied concrete from the hopper 13 is thus embraced by the sleeve in readiness for the next forward stroke.

This arrangement of the pump permits the adjustment of the length and position of the stroke of the sleeve, of the speed of the forward stroke and of the acceleration of the rear stroke, and consequently the frequency of the reciprocation can be adjusted. This enables the pumping cycle to be regulated to suit the particular mix of concrete being employed, in order that the greatest amount of each part of the pumping cycle may be carried out under the favourable pumping conditions described above.

In a modification to this embodiment, illustrated in Figure 3, the bore of the sleeve 11, instead of being of uniform cross-section throughout, is provided with a divergent portion 60 leading to a portion of the sleeve at the forward end 18 which is of slightly greater internal diameter than the internal diameter of the remainder of the sleeve. This alteration in the cross-sectional area of the bore of the sleeve, which may be as little as 2%, produces a choking action which has a noticeable effect in initiating the desired jamming action of the concrete in the sleeve during the forward stroke only of the cycle.

In this embodiment an injector tube 61 is provided leading into the stationary barrel 10 near its outlet end 19, and additional water is injected through the injector 61 into the stream of concrete being pumped through the flexible hose 20, thereby reducing friction in the hose 20. Excess water is withdrawn from the concrete in the hose 20 before it emerges into the mould or framework 62, by means of suction applied to a suction pipe 63 leading into a suction jacket 64 surrounding a short length of the pipe 20 provided with perforations 65.

In the case of a pump whose outlet is fitted with an extrusion orifice surrounding an internal core, for the purpose of producing an extruded article, a change in the cross-section of the bore of the reciprocating sleeve would generally be obtained by change in core size, for example as indicated in Figure 4 in which a core 70 extending within the bore of the reciprocating sleeve has a

divergent portion 71 interconnecting its end portion 72 and a portion 73 which is of slightly larger cross sectional area.

What I claim as my invention and desire to secure by Letters Patent is:

1. A pump for pumping wet concrete in the plastic state, which comprises a hollow reciprocable tube having an inlet adjacent one end and having its other end open as an outlet leading to a receiver, means for supplying the concrete to the interior of the tube through the inlet, and reciprocating means for causing the tube to reciprocate in the axial direction in such a manner that the linear acceleration given to the tube during its movement on its forward stroke towards the receiver is so low that there is little or no slip between the tube and the concrete contained in it during the majority of the forward stroke, whilst during the majority of the return stroke the linear acceleration given to the tube is so great that there is slip between the wall of the tube and the concrete contained in it.

2. A pump as claimed in claim 1 in which the reciprocating tube slides within the bore of a stationary outer tube one end of which leads to the receiver.

3. A pump as claimed in claim 2 in which the receiver comprises a pipe one end of which is secured to the end of the stationary tube.

4. A pump as claimed in claim 3 including means for injecting additional water into the stream of concrete being pumped near the outlet end of the stationary outer tube.

5. A pump as claimed in claim 4 including means for applying external suction to a perforated length of the pipe near its outlet end to remove excess water from the stream of concrete being pumped through the pipe.

6. A pump as claimed in claim 1 in which the reciprocating means comprises a piston in a cylinder, the piston being connected to the reciprocating tube by a piston rod, liquid under hydraulic pressure being admitted to the cylinder on one side of the piston to drive the reciprocating tube on its forward stroke.

7. A pump as claimed in claim 6 in which compressed air is admitted to the cylinder on the other side of the piston to drive the reciprocating tube on its return stroke when the hydraulic pressure in the cylinder is released.

8. A pump as claimed in claim 7 in which the cylinder is provided with a poppet valve which when opened releases the hydraulic pressure, and which includes a spring-pressed bolt arranged to fly forward at a predetermined point in the forward stroke of the reciprocating tube to strike the tail of the poppet valve and open it.

9. A pump as claimed in claim 8 in which the bolt is held in its rear position by a spring-loaded ball catch, and in which a connecting rod secured to the reciprocating tube increases the forward pressure of the driving spring on the bolt until at the desired point the ball catch is overcome and releases the bolt, and in which at the end of the return stroke the connecting rod restores the bolt to its rear position in which it is again retained by the ball catch.

10. A pump as claimed in claim 2 in which the concrete is supplied under gravity to the inlet of the reciprocating tube through a stationary hopper, the inlet to the reciprocating tube comprising an elongated slot which is in register with the mouth of the hopper at all points of the forward and return strokes of the tube.

11. A pump as claimed in claim 2 in which the bore of the reciprocating tube includes a section in which the inside wall of the tube diverges toward the outlet end.

12. A pump as claimed in claim 2 in which an extrusion core extends within the bore of the reciprocating tube in the region of its outer end.

13. A pump as claimed in claim 12 in which a portion of the length of the extrusion core is of divergent form.

14. The method of using an open-ended hollow tube for pumping unsaturated concrete through a pipe, com-

prising filling the tube with unsaturated concrete, inserting the open end of the tube in said pipe in alignment therewith, then successively urging the tube forwardly in a lengthwise direction into the pipe to move forwardly the tube contents in ramming engagement with any concrete already in the pipe, whereby to propel the latter through the pipe, the linear acceleration of the tube during such forward movement being sufficiently low to avoid slippage between the tube and its contents due to inertia, and suddenly partially withdrawing said tube from the pipe with a sufficiently great degree of linear acceleration to cause slippage between the tube and its concrete contents due to inertia of the latter.

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