Advance Equipment for Compaction on Site

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Abstract Compaction is very important in construction of plinth in building. The contractor needs the densest and stable earthwork obtainable at lowest price. Now a day's plinth filling is not completed within stipulated time due to lack of workers. The problem of settlement of floor finish occurs due to poor compaction. Now day's vibrator is used for compaction of plinth, but it is harmful to operator which causes Reynaud's Syndrome with symptoms that include numbness and tingling in the fingers, and ultimately loss of sensation and muscle. Hence to overcome this problem we have made an attempt to design the impact type of compaction machine which increases the density of soil and reduce the settlement of floor finish. The demands for labour have been reduced by introducing this compaction equipment as well as all the disadvantages of the vibrator have been overcome. This advanced compaction equipment can be fabricated with the locally available material, and transported easily. The cost of the Plate Compactor present in market is nearly in range of Rs.30,000 – Rs.35,000, but the Compaction Equipment designed by us would probably be cheaper than the Plate Compactor. The estimated cost of Compaction Equipment will be nearly equal to Rs.20,000.

Keywords — ***Compaction Equipment, Plinth, Reynaud's Syndrome, Vibrator, Plate Compactor.***

I. INTRODUCTION

Soil compaction is vital part of the construction process. It is used for support of structure entities such as building foundations, roadways, walkways and earth retaining structures to name a few. Recents systems may be distinguished relating to the way of excitation (periodical or transient), to the location of impact (surface or in the depth) such as to the achievable depth of influence [1]. For a given soil type certain properties may regard it more or less desirable to perform adequately for a specific circumstance. Worldwide a large number of soil compaction system was developed in recent decades [2]. In general, the preselected soil should have sufficient quality, be generally incompressible with the goal that future settlement is not significant, be steady against volume change as water content or different factors change, be durable and safe against deterioration and possess appropriate permeability. The PIV method is particularly used in fluid mechanics and in long-term studies, but can also be used to assess the displacement field of dynamic soil compaction by a pairwise comparison of discrete image areas [3, 4]. Determination of adequate compaction is done by determining the in-situ density of the soil and comparing it to maximum density determined by the laboratory test. The most commonly used laboratory test is known as the Proctor compaction test and there are two distinct techniques in obtaining the maximum density. They are the standard proctor and modified proctor tests; the modified proctor is commonly used. As per standard procedure of modified proctor test, we give certain amount of impact energy to the soil, so that the soil gets compacted effectively giving Maximum Dry Density (MDD) conforming to minimum settlement in future. While the ability of the technology was verified to a partial extent, the commercial receipt of the technology depends on the modification and the development of a marketable prototype that is rugged and easy to use [5]. Now-a-days, plate compactor is widely used in construction industry for compaction which is small in size giving results in less time. But, it weighs more than 200kgs and hence it causes difficulty in transportation. And also it doesn't have reversible motion. As the machine works on vibration principle, the labours operating the machine suffers from Raynaud's Syndrome. To overcome this disadvantages and to modify the equipment, we are working to design a "COMPACTION EQUIPMENT" by following the standard procedure. Very tall soil difficulty in mixture with disadvantageous roller constraints can cause chaotic motion of the drum. In this operating mode the roller cannot be precise [6].

II. MATERIALS AND METHODS

Plate Compactor

Plate compactor is an indispensable construction equipment that is used to compress different types of gravels and soil. Mainly they consists of steel plate which is mounted on the base of the machine as shown in figure 1 Plate compactor have various design and attachments, however the core is a flat and heavy plate which is driven or vibrated up down with either gasoline or diesel power engine. Rolling compactor is usually used at a job site where house or larger

 DOI : 10.35291/2454-9150.2021.0099

ISSN : 2454-9150 Vol-06, Issue-12, MAR 2021

construction structure is being built because it is too big for a small project. The walks - behind units, features a lawn mower and are used for smaller areas, while larger units have greater force and power but are also more expensive and difficult to operate. To conclude, larger the plate compactor, greater the force produced.

Fig. 1. Plate Compactor

When the area to be compacted is confined and the rollers are not appropriate a vibrating plate compactor is used.

Drawbacks

The some of the main drawbacks observed in plate vibrators are as follows:-

- Plate compactor do not have the ability to compact deeper amount of soil that is the effective depth of influence is less, because the force from the plate is more direct.
- The machine can be difficult to transport, especially when it is turned off, and it will usually require two people to transport the machine to a job site.
- Vibrator is harmful to operator which causes Raynaud's Syndrome with symptoms that include numbness and tingling in the fingers, and ultimately loss of sensation in muscle.
- The efficiency of plate compactors is very low i.e. the applied energy is very less affecting the result of compaction.

Concept

In the process of compaction, mechanical energy is applied to a soil mass so as to rearrange its particles and reduce the void ratio. Compaction is applied to soil masses to improve their properties or in the process of placing fill, such as those in the construction of embankments, road bases, runways, earth dams and reinforced earth walls. In the compaction process, there is usually no change in the water content and in the size of the individual size particles.

To ascertain the degree of compaction, the dry unit weight is used which is an indicator of compactness of solid soil particles in a given volume. The laboratory test is needed to establish the maximum dry density (MDD) attained for a given soil with a standard amount of compactive effort. A number of samples of the soil are compacted at different water content, and dry density vs. water content relationship is plotted as shown in the below fig 2.

The resulting plot generally is characterized by a distinct peak. The modified "V" curves as appeared in figure 2 are obtained for cohesive soils (or fine grained soil), and are known as compaction curves.

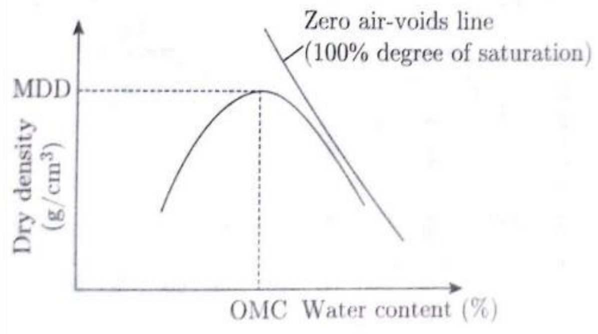


Fig. 2. Compaction Curve for Cohesive Soil

In the test the dry density cannot be found directly, hence the bulk density and the moisture content are obtained first to calculate the dry density as:

$$\gamma_d = \frac{\gamma t}{1+w}$$

Where, γ_t = Bulk Density, w = Water Content

As per IS recommendation the tests for compaction are as follows:

There are two types of major tests:

1. Standard Proctor Test

The total compaction energy by this test is given by

$$E = \frac{Whnl}{Vm} = \frac{24.5\times.3\times25\times3}{850\times10^{-3}} = 595 \text{ KJ/m3}$$

On field, if the energy is given according to standard proctor test, the results obtained shows major difference between the field and laboratory tests. Thus, in actual practice it is necessary to give more energy and hence we adopt modified proctor test.

Modified Proctor Test

The total compaction energy by this test is given by,

$$E = \frac{Whnl}{Vm} = \frac{48.02\times450\times10^{-3}\times25\times5}{850\times10^{\wedge}-3} = 2670 \text{ KJ/m}^3$$

Figure 3 below shows a zero air voids line. It is observed that maximum dry density obtained by modified proctor test is lower than theoretical dry density denoted by zero air voids line. The line joining the optimum dry density is called line of optimum, and it is roughly parallel to zero air voids line.

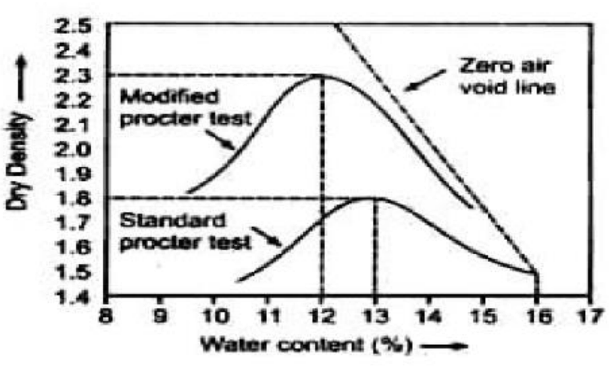


Fig. 3. Compaction Curve of Standard Proctor and Modified Proctor Test

DOI : 10.35291/2454-9150.2021.0099

ISSN : 2454-9150 Vol-06, Issue-12, MAR 2021

III. EXPERIMENTATION AND RESULT

Mechanisms

We have studied various mechanism, some of the mechanisms we found useful for design of our equipment.

1. Cam Mechanism:

Cam is a rotating or sliding piece in a mechanical linkage utilized particularly in changing revolving movement into linear motion. It is regularly a piece of a rotating wheel or shaft that strikes a lever at one or more points on its circular way. The cam can be a straightforward tooth, as is utilized to convey pulses of power to a steam hammer.

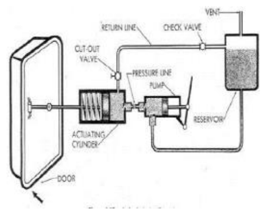
2. Poppet Valve Mechanism:

A poppet valve additionally called mushroom valve is a valve regularly used to control the timing and amount of gas or fume stream into an engine. It consists of a hole, ordinarily round or oval, and a tapered plug, usually a disk shape on the end of a shaft also called a valve stem.

3. Geneva Mechanism:

The Geneva drive or Maltese cross is a gear mechanism, wheel is typically equipped with a pin that ventures into a slot-shaped groove situated in the other wheel (driven wheel) that progresses it by one step at a time.

4. Hydraulic Mechanism:



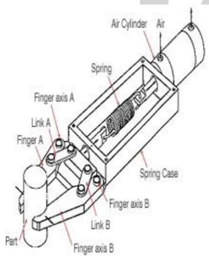


Fig. 7. Hydraulic Mechanism **Fig. 8. Pneumatics Mechanism**

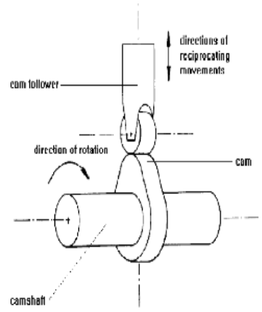
A hydraulic drive system is a drive or transmission system that uses pressurized hydraulic fluid to power hydraulic machinery. the term hydrostatic refers to the exchange of energy from flow and pressure, not from the kinetic energy of the flow. A hydraulic drive system comprises of three parts: The generator (e.g. a hydraulic pump), driven by an electric motor, combustion engine or windmill; valves, piping, filters, etc.

We have studied various mechanisms and the advantages and disadvantages of each. After studying thoroughly we felt the hydraulic and pneumatic mechanism seems to be useful for us.

5. Pneumatics Mechanism:

Pneumatics is a branch of engineering that creates use of gas. Pneumatic systems used in industry are commonly powered by compressed air or compressed inert gases.

A centrally situated and electrically powered compressor powers cylinders, pneumatic devices and air motors, A pneumatic system controlled through manual or automatic solenoid valves is selected when it gives a low cost, high flexible, or safer alternative to electric motors and actuators. Pneumatics also has applications in dentistry, mining, construction, and other areas.



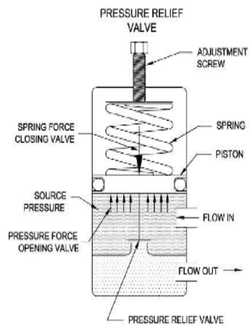


Fig. 4. Cam Mechanism **Fig. 5. Poppet Valve Mechanism**

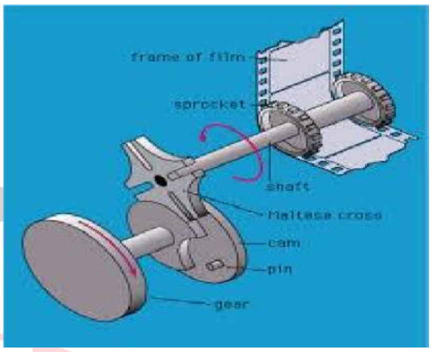


Fig. 6. Geneva Mechanism

Finalization of mechanism

Pneumatic mechanism:

Pneumatic cylinders s shown in the fig 9 are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion.

Like hydraulic cylinder, something forces a piston to move in the longing direction. The piston is a disc or cylinder, and the piston rod moves the force creates to the object to be moved. Engineers in few cases want to use pneumatics since they are cleaner, quieter, and don't need more amounts of space for fluid storage. Since the working fluid is a gas, leakage from a pneumatic cylinder will not trickle out and contaminate the surroundings, making pneumatics more attractive where cleanliness is a requirement.

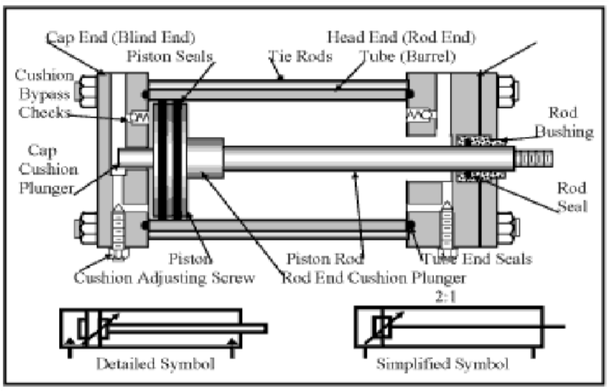


Fig. 9. Components of Pneumatics Cylinder

 DOI : 10.35291/2454-9150.2021.0099

ISSN : 2454-9150 Vol-06, Issue-12, MAR 2021

Types of Pneumatic Mechanism:

1. Single Acting Cylinders
2. Double Acting Cylinders

Advantages of Pneumatic Mechanism

Machines are easily structured utilizing standard cylinders and other components, and work by means of basic on-off control.

Pneumatic systems generally have long operating lives and enquire little maintenance. Because gas is compressible, hardware is less liable to stun harm. Gas absorbs excessive force, whereas fluid in hydraulics legitimately moves force. Compressed gas can be stored, so machines despite complete run for some time if electrical force is left.

There is a very low chance of fire compared to hydraulic one.

Components

1. Pneumatic Cylinder

Pneumatic cylinder (sometimes known as air cylinder) are mechanical devices which use the power of compressed gas to produce a force in a reciprocating linear motion.

2. Compressor:

A compressor is a mechanical device that increases the pressure of a gas by reducing its volume. An air compressor is a particular type of gas compressor. Compressors are like pumps: both increase the pressure on fluid and transport the fluid through a pipe. As gases are compressible, compressor also minimizes the volume of a gas.

3. Directional Control Valve (DCV):

Directional control valves are one of the most fundamental parts in hydraulic machinery as well as pneumatic machinery. They permit fluid flow into various ways from at least one sources. They as a rule comprise of a spool inside a cylinder which is mechanically or electrically controlled. The movement of the spool restricts or allows the flow, thus it controls the fluid flow.

4. Connector:

A quick connect fitting also called a quick disconnect or quick release coupling, is a coupling used to provide a fast, make-or break connection of fluid transfer lines. Worked by hand, fast connect fittings replace threaded or flanged connections, which require wrenches. When equipped with self-sealing valves, fast connect fittings will, upon disengagement, automatically contain any fluid in the line.

5. Pneumatic Tube:

Pneumatic tubes (or capsule pipelines; also known as pneumatic tube transport or PTT) are systems that propel cylindrical containers through networks of tubes by compressed air or by partial vacuum. They are utilized for transporting solid objects, as opposed to conventional pipelines, which transport fluids.

6. Wheels:

We have provided wheels for easy transportation of frame within the construction site. As the frame is light in weight it is easy to transport the frame easily with the help of wheel. The wheels provided in our equipment are of plastic.

7. Frame:

The frame used in our equipment is made of material mild steel.

As the mild steel bar are light in weight, strong, durable and have the tendency to resist corrosion. Therefore this material is most suitable for our equipment. The design of frame structure is based on plate size, pneumatic cylinder height and height of fall of plate.

The design of frame is such that its height is divided in two parts. The top most part consist of small aluminum bars, which are parallel to the designation of plates, and the intermediate part which divides the frame in two parts consist of the bar which are perpendicular to the designation of plates. This is designed in such a way so as to overcome the moment developed due to the impact action of the plates.

8. Plate / Dead Weight:

The material used for the plate (weight) in our equipment is cast iron. Cast iron is a part of iron-carbon alloys with carbon content more than 2%. Its usefulness derives from its relatively less melting temperature.

9. U Clamp:

A clamp is a fastening device used to secure or hold objects tightly together to prevent movement or divide through the application of inward pressure.

Fig. 10. Components

IV. Design and Specifications

Specification: After the design and analysis following are the specification proposed for the innovative equipment proposed.

 DOI : 10.35291/2454-9150.2021.0099

ISSN : 2454-9150 Vol-06, Issue-12, MAR 2021

Table -1 Design and Specifications

Height of Fall : 45 cm	Number of Plates: 2	Number of blows : 20/min
Number of layers : 3	Depth of murrum : 30 cm	Energy Required : 618.03 kJ/m^3
Frame Height : 90 cm	Compressor used : 8 bar	Diameter of Cylinder : 5 cm
Height of Cylinder : 45 cm	Diameter of pneumatic tube: 1 cm	
	Connector Size	
C_1 = 1.2 cm ×1 cm	C_2 = 1.2 cm × 1 cm	C_3 = 1.2 cm × 1 cm
C_4 = 1.2 cm × 1 cm	C_5 = 1 cm × 1 cm × 1 cm	C_6 = 1 cm × 1 cm × 1 cm

V. RESULTS AND DISCUSSION

The actual force required in the application is need to move the engine valve along with spring that must be considered.

Calculation of Force Required:

Air Density = 1.02 Kg/m^3

Number of blows/min = 20 blows/min

Distance in one blow = 45 cm=0.45m

Area of the cylinder=$\frac{\pi}{4}\times D^2$

Let D = 5 cm=0.05 m

Area of cylinder = 1.964×10^{-3} m^2

A)Cylinder force to move weight=20×2×10=400 N

B) Acceleration required=a=$\frac{0.075-0}{0.5}$=0.15 m/s^2

Force required for acceleration=ma =$\frac{400*0.15}{10}$=6 N

Total force = 400+6= 406 N= 410 N

Power required = F × V =410×0.075=30.75 W

We have,

Power Loss(kw) = $\frac{Q\times\rho\times g\times h}{3.6\times10^6}$

Q = AV =$2\times1.964\times10^{-3}\times0.075\times3600$=1.06 m^3/hr.

Power Loss (kW) = $\frac{1.06\times1.02\times9.81\times0.45}{3.6\times10^6}$=$1.325\times10^{-6}$

kW=1.325×10^{-3} W

Total Power = 30.75+1.325×10^{-3} = 32.07 =35 W

Calculation of Pressure required:-

Assumed data-

- Diameter of cylinder, D = 5cm
- Length of cylinder, l = 45cm
- Diameter of pipe, d = 1cm
- No. of blows per minute=20
- Volume of cylinder= $\frac{\prod D^2 l}{4}$= 0.8835×10^{-3}m^2

Time required for single blow = 60/20 = 3 sec

Discharge=$\frac{Volume\ of\ cylinder}{Time\ for\ single\ blow}$

Q = $\frac{0.8835\times2\times10^{-3}}{3}$ = 5.89×10^{-4} m^3/sec

According to continuity equation,

Where, Q = A_1V_1=A_2V_2

A_1= Area of Cylinder, A_2= Area of pipe, V_1= Velocity of flow from cylinder, V_2=Velocity of flow from pipe.

Here, Q = A_2V_2

V_2 = Q/A_2= $\frac{5.89*10^{-4}}{\frac{3.14}{4}*10^{-4}}$= 6.5 m/sec

Now,

Area of cylinder=$\frac{\pi D^2}{4}$ = $\frac{3.14*0.05^2}{4}$=1.96×10^{-3} m^2

Pressure= $\frac{Force}{Area}$ = = $\frac{2*10*9.81}{1.96*10^{-3}}$ = 105 N/m^2= 1 bar

Thus, Pressure required is 1 bar.

Calculation for cross-section of frame:

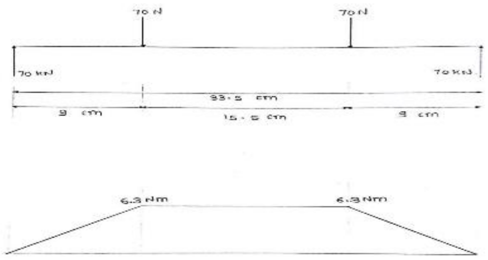


Fig. 11. Bending Moment Diagram

Assume,

Thickness of section = 2mm

Permissible stress = $\frac{Yield\ stress}{factor\ of\ safety}$

$\sigma = \frac{250}{1.5}$ = 166.67Mpa According to flexural formula,

$\frac{M}{I} = \frac{\sigma}{y}$

Where,

M = Bending moment, I = Moment of Inertia of section, Y = Depth of neutral axis

I = $\frac{b^4}{12} - \frac{(b-2t)^4}{12}$

y = b/2

Solving for b using t = 2mm, we get,

B = 6.128 mm

Let us use 14 mm × 14 mm hollow section with 2 mm of thickness.

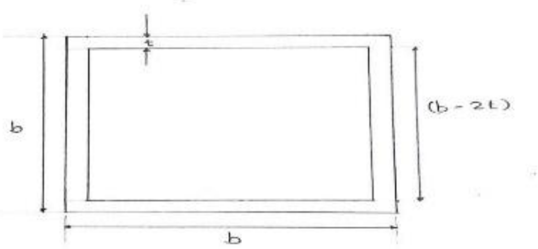


Fig. 12. Cross Section of Mild Steel Bar

Assembly of Equipment

Our equipment has special feature that it can be dismantle up to a certain extent and hence transportation of equipment becomes easy. The equipment consist of various components and they are as Frame, Pneumatic cylinders,

Equation (4.2.3)

DOI : 10.35291/2454-9150.2021.0099

ISSN : 2454-9150 Vol-06, Issue-12, MAR 2021

Plates/weight (weighing 10 kg each), Rubber bush, Pneumatic pipes, Connectors, Directional control valve, Compressor. The wheels has been attached to the frame via welding. The handle of the frame can be dismantled or assembled with the help of nut bolts.

Operation of Pneumatic Cylinder

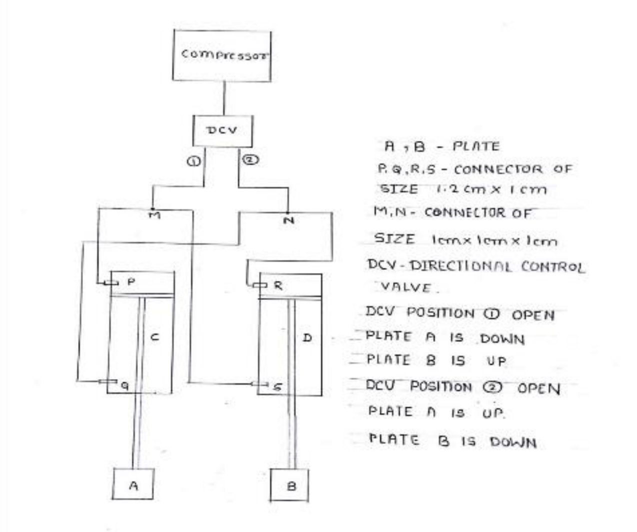


Fig. 13. Circuit Diagram showing working of Pneumatic Cylinder

As per our design and for effective working of the equipment we desired to have alternative impact of the weight on the murrum, so that twenty (20) numbers of blow per minute would be achieved with maximum efficiency as per our designation. The connection of pneumatic tubes plays the vital role for the motion of the plates. The connection of pneumatics tubes can be arranged in both the ways i.e. alternative and simultaneous motion of the plates can be achieved. The connectors through which the connection of pipes are attached to the cylinder from DCV divides the flow of the air.

As we desired the alternative motion of the plates, we made the connection of the plates as shown in the figure 14 above. The air is pressurized from the air compressor and is supplied through tubes to DCV (Directional Control Valve). The main function of the DCV is to give direction to the pressurized air. As shown in the figure 14, the pneumatic tube 1 and 2 shows the flow of air from air compressor through DCV.

The M and N shown in figure plays the role of three way connector. Through connector M the flow of air gets divided in two parts, out of which one is given to the inlet of cylinder C because of which the piston of cylinder C get extended and the plate A gives impact on the murrum. Thus, one blow is completed. And the flow of air is given to the outlet of the cylinder D because of which the piston of cylinder D retract and plate B moves upward. Through connector N also the flow of air gets divided in two parts, out of which one is given to the inlet of cylinder D because of which the piston of cylinder D get extended and the plate B gives impact on the murum. Thus, second blow is completed. And the flow of air is given to the outlet of the cylinder C because of which the piston of cylinder C retract and plate a moves upward. Similarly the operation of the plate continues in the same pattern as explained above.

This all operation of the plate is operated through the key provided on DCV, which controls the motion of the plate. Once the key of DCV is pressed one blow of each plate is completed. When one blow of the each plate is completed the compressed air is released to the atmosphere through the bore holes provided in Directional Control Valve (DCV).

VI. Conclusion

Based on the study, analysis and design of the innovative compaction equipment, it is concluded that study of various mechanisms has been carried out and an advance compaction equipment have been successfully developed that overcomes the disadvantages of plate compactors available in the market in the plinth filling. It is designed as per the requirements as well as demand from construction industry. It is also observed that by this advanced technology, the demand of labor can be reduced. It is further observed that if cost of this innovative compaction equipment is compared with the equipment's already available in the market, it will certainly be cheaper solution for the local contractors.

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 DOI : 10.35291/2454-9150.2021.0099