DESIGN AND FABRICATION of HIGH VELOCITY IMPACT PLASTER MACHINE

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ABSTRACT

The construction industry is continuously struggling to adopt methods which are most fit to meet the competition level at construction site. As most of the construction is accomplished by men and further, lack of skilled labor, increase in labor cost, and technological advances are forcing rapid changes in building construction, which mainly consists of commercial infrastructure and residential building, where plastering work is must. As manual plastering is very time consuming and huge labor skills are required to accomplish it. So the aim of this project is to design such a method or machine which reduce labor work and working time at plastering site and intend to design a mortar spraying machine named (High Velocity Impact Plaster Machine), This machine is used to spray the mortar with a higher impact which minimize the bouncing back of the mixture from the wall and also making the surface finish good and at the same thickness. The advantages of using this machine are for saving in man power, raw material and total construction time specifically plastering time and indirectly it reduces the labor cost and hence total construction cost. Further this machine is also very easy to operate and don't require any high labor skills and is very easy to maintain. Additionally. Plastering is widely used as a finishing technology for both interior and exterior walls made from bricks. The plastering wall machine will help to save labor work ,increase productivity by many times, get professional quality finishing in less time, reduce cost, manufacture plastering wall machine in low cost.

KEYWORDS: *High Velocity, Plaster Machine, Construction Industry, Increase Productivity, Cost Reduction*

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1. INTRODUCTION

Since the era of 21th century is very modern and fast and there is competition everywhere, people are trying to make high sky-scrappers and many other projects, every construction project need to be finish by the due time, due to competition as well as to save the labor cast, So the use of high labor skill and new technology is required to finish the given task. Since Construction sector is responsible for a progress of any country, because most of the growth of the nation is depending upon industries, factories, offices, schools, colleges etc. and they all required a well-constructed building. Construction site is a biggest economic sector because of it the development trade in most countries amounts to 10-20% [1] of the total national product, still due to labor demand and most of the work is repetitive it is a slow manual process. So to improve the economic growth and indirectly developing the lifestyle of the country's people there must be need of improving the techniques of working. Construction sector is a sector which required more time and money, having very slow and stepwise process.

In today's construction sector all most all the processes are manual which required more time for their completion. Due to which the cost of the project is high, as there is a lack of labor skills so to meet the modern construction competition a tactics should be develop to convert such manual process into automatic or semi-

automatic process hence it must be necessary to automate the processes in the construction work and improve the efficiency of it. Wall plastering is the main and compulsory step among the processes followed in the building construction, which is used in construction to get smooth and finished wall surfaces. Plastering is also essential step to give proper strength to the walls; it also avoid the walls from moisture. It also gives a good look to the walls and ultimately creates best residential condition in the particular room. But presently wall plastering is being done manually in most of the construction buildings by use of the labor skills. Due to which the process is lengthy and time consuming. So this is an initiative towards the automation in plastering technique.

The rising trend of nuclear families in urban areas has increased the demand for high-rise residential buildings, which besides providing the required security also offer amenities like gyms, swimming pools, and club houses to attract buyers. The increased demand for high-rise buildings provides ample potential for spraying and plastering machine vendors to cater to the market. Also, these buildings often incur extra labor cost as workers' safety becomes paramount due to the higher elevation levels. This problem can be overcome by using spraying and plastering machines, which require minimal supervision during their operation.

To initiate our idea, our target area is construction sites in Pakistan at different dams, huge buildings, plazas, markets, offices, schools, homes and other construction sites. Our machine belongs to construction side so that's why our primary focus is on the potential consumers and also those markets that are in touch with construction (Construction companies and Contractors) at a high and low level.

Pakistan is under developed country and is trying to develop from many aspects. The population is rapidly increasing day by day in Pakistan which demands for shelters, and indirectly offices, buildings, markets, and plazas, simply the construction is growing day by day. Plastering is one of the most important part of construction. Due to manual process of wall plastering on construction site, there is a huge scale requirement of labor and hence the labor cost is responsible for increasing the price of construction or project work. The quality of work is mostly depending on the skill of the labor work in manual plastering process. The solution of these problems is just to automate the process, so that there will be a saving of period and cost and getting good plaster finishing to the walls. The plastering machine can plaster the walls automatically and very smoothly. Due to which the process will fast and there will be saving of cost and time this will helps to reduce the total cost, total time which ultimately responsible for the growth and hence the progress rate of a country is going to increase.

1.2 Problem Statement

In the manual plastering technique, the most crucial factor is skilled labor because of which plastering has been done on the walls, but in today's modern era there is lack of skilled labors due to which it is very inconvenient to complete this process hardly there are few labors which can do such job perfectly and can do such job by using their skills. But for doing such manual plastering labor requires more time to finish the process which increases their wages and hence the total plastering or labor cost increases also there is wastage of time. Since the 21st century is the era of revolution and competition, people are trying to build high buildings and sky-scraper. Many modern buildings, schools, colleges, offices, apartments, have been built and many are in construction processes. Due to manual process of wall plastering on construction site, there is a huge scale requirement of labor and hence the labor cost is responsible for increasing the price of construction or project work. The quality of work is mostly depending on the skill of the labor work in manual plastering process. But there is a huge lack of labor skills.

1.3 Objective

From the above discussion about old plastering techniques, problems in old plastering techniques, their downsides, background of the plastering method and the decided aim to be achieved following are some objectives that have been decided.

- This Machine will reduce the human work.
- It will be straight forward in construction and simple to control.
- Higher excellence of the plaster can be acquired.
- It will be moved horizontally from one place to another. So that it will be portable.
- It will assist to save labor cost.
- It will avoid wastages of the mortar, thus to save the cost.
- Machine cost will be less than existing machines.
- Can be used by unskilled person.
- It can easily be maintained.

2. LITERATURE REVIEW

The advancement in automation of concrete and asphalt mixing was already achieved in the sixties, the development in mobile construction machinery first began with the introduction of microelectronics in the beginning of the eighties. For years the personnel, technological and economic conditions for the automation of construction machinery and plants in Europe were characterized by an extensive lack of skilled workers and a growing average age of the staff, demands for effective humanization of nearly all construction works, increased requirements on the quality of the work execution, a need for works in dangerous and inaccessible areas of operations, an increase in performance and reduction of costs for improvement in economy, and by the competition on international markets of construction machinery [2]. Plastering is widely used as a finishing technology for both interior and exterior walls made from bricks, concrete or timber. While plastering of exterior walls provides heat insulation, sound absorption and protection against air pollution and weather, the application of plaster to interior walls improves the indoor climate by humidity regulation and serves the purpose of compensating inevitable tolerances of the brickwork, thus providing a clean, level surface for further finishing tasks [3].

Although plastering is one of the most physically strenuous jobs in building construction it was not before the early fifties that machines were developed which supported this strenuous task. The first machines to be developed were automated mixers which made the task of manual plaster mixing obsolete [4, 5]. The rapidly developing area of construction automation leads construction managers to critically evaluate the feasibility of replacing conventional construction processes by automated systems. This decision requires careful analysis of tangible and intangible factors such as need-based criteria, economic criteria, technological criteria, project specific criteria, and safety/risk criteria. [6]. The introduction of plastering machines such as RUMA 1, Putzmeister KS 1 [7] and Putzmeister Gipsomat [8] in the sixties was considered revolutionary and marked the beginning of a new plastering technology.

The development of the AMPA machine [9] was the first attempt to significantly increase the level of automation but this kind of equipment has never been accepted in practice. Automated spraying of mortar and paint has recently been demonstrated by means of the mobile articulated prototype robot TAMIR which had been developed in Israel [10] and a prototype of an artesian robot which had been constructed in a Swedish joint venture between Swedish construction companies and universities [11]. Unfortunately these developments have been unable to provide a breakthrough in the

plastering industry. Thus, even today, the plastering machines developed in the sixties such as [7,8] are still considered to be State-of-the-Art.

This study has presented an invention that provides a simple efficient, portable and reliable device that spray the mortar with a higher impact reducing the risk of wasting the raw material, and minimizing the man power, and plastering time and thus reducing the total construction cost by reducing the labor cost upto great extent. The readymade mortar is carried from the hopper in the pipe by a driving motor to the nozzle and is sprayed by means of pressurized air compressor through the nozzle and resulting in a uniform spray of mortar layer over the wall.

3. DESIGN CALCULATIONS

3.1 Area to be covered

Our first assumption is, we are assuming an area of (30*12-ft) which is 360 ft². So our assumption is to cover this area in 1-hr, this means that our Rendering width would be 360ft²/hr. So we are aiming to design a plaster machine for 360 sft/hr.

As

$$360 \text{ ft}^2 / h = 1 \text{ ft}^2 / x \text{ min}$$

$$360 \text{ ft}^2 / 60 \text{ min} = 1 \text{ ft}^2 / x \text{ min}$$

$$360 \text{ ft}^2 / \text{min} = 60 \text{ min. ft}^2$$

$$x = 0.16 \text{ min}$$

or

$$x = 9.9 \text{ sec}$$

So our design criteria is to cover an area of 1 ft² in 9 to 10 sec.

3.2 Impact Velocity

This is our main assumption, while manual plastering a labor or plasterer is standing at a distance of about **1.5 ft** from the wall which is almost **0.4572 m**. So we have calculated the velocity of the manual plastering. We used a stopwatch multiple times and recorded the time from throwing mortar through Trowel and hitting the wall and then we took the average, by this way we find the time taken. Our results are:

$$T1 = .025 \text{ sec}$$

$$T2 = .020 \text{ sec}$$

$$T3 = .023 \text{ sec}$$

$$T4 = .021 \text{ sec}$$

So

$$\text{Average time} = T1 + T2 + T3 + T4$$

$$T_{\text{avg}} = .025 + .020 + .023 + .021$$

$$T_{\text{avg}} = .022$$

Figure 1: Schematic of top view of Hopper/ Surge Tank

Now as a plasterer stay at a distance of .4572 m from the wall so calculating the velocity of manual plastering.

$$V = S/T$$

$$V = .4572 / .022$$

$$V = 20.78 \text{ m/s}$$

So almost a plasterer apply 21 m/s while performing manual plastering.

As we are designing a machine so we must have to keep the velocity maximum, we assuming a factor of safety let's assume 1.5 ,so we are aimed to design a machine a with an impact velocity from

30 m/s to 35 m/s.

3.3 Hopper/Surge Tank design

Here $X=26\text{in}$, $Y=17\text{in}$.

$x=12\text{in}$, $y=6\text{in}$, $H=19\text{in}$

$$\text{Volume of Hopper} = \frac{H}{3} \frac{(X^2Y - x^2y)}{(X-x)}$$

$$V = \frac{19}{3} \frac{(26^2 \times 17 - 12^2 \times 6)}{(26-12)}$$

$$V = 4807.69 \text{ in}^3$$

Or

$$V = 78 \text{ Litre}$$

3.4 Motor Selection

For motor selection we have to select a motor which carry the load applied by the mortar So first we have to find the Force applied by the mortar as it falls on the shaft Gear due to gravity. Now our aim is to select the motor which can push this applied Load and the load of the rotating gear shaft.

So, first finding the pressure at the cylindrical region.

Applying Bernoulli's equation b/w section 1 and 2.

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho gh_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho gh_2$$

Now here in static condition there is only gravitation force and motor is not yet connected so $V_1=0$ and $V_2=0$, Also the elevation at point 1 is zero.

So the equation is reduced to

$$P_1 = P_2 + \rho gh_2$$

Here P_2 is at atmospheric pressure as pipe is not yet connected. And $\rho = 2180 \text{ kg/m}^3$ which is already known for concrete mixture, $h_2 = 38 \text{ in} = 0.9652 \text{ m}$.

So

$$P1 = 1 + 2180 \times 9.8 \times 0.9652$$

$$P1 = 20681.5 \text{ pa}$$

Now force exerted by this mortar at static position is given by:

$$F_{st} = \frac{P1}{A1}$$

$$F_{st} = \frac{20621.5}{\pi r^2}$$

$$r = 4 \text{ in} = 0.4064 \text{ m}$$

$$F_{st} = \frac{20621.5}{3.14 \times 0.4064^2}$$

$$F_{st} = 1615.4 \text{ N.}$$

This is the force of the mortar only, now the motor has to overcome both the force of mortar and rotating shaft so finding the force of rotating shaft now.

Now let's assume we are selecting a 3Hp motor so our calculation is for a 3hp motor. The torque for the shaft delivered from an electrical motor producing 3hp at speed 1500 rpm can be calculated

$$T = \frac{hp (63,025)}{n}$$

- Where hp is the horse power
- N is the number of revolution

$$T = 126.05 \text{ lbf in}$$

The bending force produced by gears is equal to the net driving force given by

$$F = T/r$$

So

$$F = 126.05 \text{ lbf.in}/3 \text{ in}$$

$$F = 42.01 \text{ lbf}$$

Or

$$F = 186 \text{ N}$$

So the net force of the mortar and the rotating shaft will be 1801N, so we have to select the motor which produces a greater impulse to overcome these forces. Now we have to select the Motor which can push this load up to the nozzle part. So selecting motor from the table. [14]

3.5 Other Nozzle Considerations

Long venturi nozzles are the industry standard for blasting surfaces that are 18 to 24 inches away for hard-to-clean surfaces or 30 to 36 inches for loose paint and soft surfaces. We recommend short-venturi nozzles for blasting distances under 18 inches. Venturi refers to the tapering within the blast nozzle. This shape decreases pressure while increasing velocity for

the abrasive. Both Silicon carbide and tungsten carbide nozzles are available with two types of threading: the standard 1-1/4" threading and the Clemco-exclusive contractor mounting thread that is wider to help prevent dust, dirt, and abrasive particles from getting stuck in the nozzle. You will need to choose a nozzle holder that has the same threading as your nozzle and the same ID/OD of your blast hose.

3.6 Hose Selection

We can select a Hose for a specific mass flow rate without any turbulences. First we will find the volumetric flow rate across this Nozzle.

3.7 Volumetric Flow Rate across the Nozzle

$$Q = AV$$

$$Q = \frac{\pi}{4} d^2 \times 35 \text{ m/s}$$

$$d = \text{nozzle dia} = 6 \text{ mm, velocity to be achieve} = 35 \text{ m/sec}$$

$$Q = \frac{\pi}{4} 6^2 \text{ mm}^2 \times 35 \text{ m/s}$$

$$Q = \frac{\pi}{4} .006^2 \text{ m}^2 \times 35 \text{ m/s}$$

$$Q = 0.0009891 \text{ m}^3/\text{sec} \text{ or } Q = 3.56 \text{ m}^3/\text{h}$$

Usually the volumetric flow rate is in m^3/h .

Now we are going to verify our assumption that whether at this flow rate our area is gonna be cover in assumed time or not, so converting the above value to ft^3/hr .

$$Q = 0.034929 \text{ ft}^3/\text{sec}$$

Or

$$Q = 0.1069 \text{ ft}^2/\text{sec}$$

Or

$$Q = 384 \text{ ft}^2/\text{h} .$$

As we have assumed an area of $360 \text{ ft}^2/\text{h}$, and by calculation we get $380 \text{ ft}^2/\text{h}$, so our assumptions are correct.

3.8 Mass Flow Rate across the Nozzle

Now to maintain this volumetric flow rate the mass flow rate through the hose is given by

$$\dot{m} = \rho Q$$

$$\dot{m} = 2180 \text{ kg/m}^3 \times 3.56 \text{ m}^3/\text{h}$$

$$\dot{m} = 7760.8 \text{ kg/h}$$

or

$$\dot{m} = 2.155 \text{ kg/sec}$$

SO this will be the required mass flow rate through the Hose pipe at any time to maintain the given volumetric flow rate to cover the desired area.

3.9 Selection Factors

One of the better ways to remember the factors and variables that go into selecting a proper slurry hose is to use the acronym STAMPED, [1] which stands for:

- S – Size (Size of inside diameter, outside diameter, and total length including fittings and tolerances)
- T – Temperature (Ambient temperature as well as the temperature of the material)
- A – Application (Configuration, routing, orientation of the hose)
- M – Material (Type of material, concentration of solids, pH level, flow rate, and velocity)
- P – Pressure (Max pressure within a system. The hose and hose end should not be rated to a pressure less than the maximum operating pressure system.)
- E – Ends (Hose style, type, orientation and attachment methods, coupled or uncoupled)
- D – Delivery (How quickly the job must be completed)

By compiling the above data about the project, you are now primed for selecting the correct type of slurry hose.

But for all these factors the hoses for mortar are already designed by the manufacturer. Now we have to select only the right dia size for our machine. so, the Nomogram below can be used to determine the hose I.D. (or dash size) that you will need. Use a straight edge to connect the flow rate that your system requires with the recommended velocity range for your application. The intersection of these two points is the required hose size. (If the line intersects between two sizes, use the next largest I.D.). [15]

Here $Q=3.56 \text{ m}^3/\text{h}$, Converting into gallons per minute= 15.67 gpm and here we are using arbitrary low velocity than the velocity at outlet which is 35m/sec.

So we will take a velocity in btw 10-15 ft/sec inside the hose for mortar.

As

$$Q = \frac{\pi}{4} d^2 \times V$$

$$d = \sqrt{(4 \times Q / \pi \times V)}$$

using $Q=0.1069 \text{ ft}^3/\text{sec}$, and $V=10 \text{ ft/sec}$

$d= 1.3 \text{ inch}$

In the left hand column, locate "15.67 gallons per minute"; in the right hand column, find "10 feet per second," which is the maximum recommended velocity range for pressure lines. A straight edge between these two points will intersect in the center column, giving you the required hose I.D. - in this case, you would need an inner diameter that is almost 33mm or (1.3") or larger. So by meeting the lines it touches the center line by almost 1.3 in, so our Hose will be of 1.3 in dia.

3.10 Compressor Selection

The main aim of the compressor here to use is to push the mortar from the speed gun at a greater impact and to attain the maximum velocity of 35m/s as we have calculated, so according to previous literature studies to attain a velocity of 35m/s we must keep a pressure of 8 bars at a delivery of 200 L/h. So we will use a compressor which maintains a constant pressure of 8 bars with Technical Specifications of:

Model No.	W-0.36/8
Voltage / Frequency	415V/50HZ
Motor	4HP/3KW Copper Wire
Tank Capacity	150Lt/40Gal
Phase	Three Phase
Head	3065 Head
Pressure	8Bar/115psi

4. MAIN GEOMETRY/ASSEMBLY OF THE MACHINE

Main geometry is classified into Assembly, Sub Assembly, and Sub-Sub Assembly. Assembly Are main parts of the project, they play a key role in any of project. They are mostly manufactured by the company, and are mostly built-in accessories of the machine.

4.1 Hopper/ Surge Tank

A hopper (bunker) designed to receive a feed at fluctuating rate and to deliver it at some predetermined rate. It acts as a storage for concrete, water, paint, powder or some other liquid or dry/wet material, it is designed such that the connecting part receives the material from the hopper on the principle of gravity.

4.2 AC Brushless Motor

AC brushless motors use the induction of a rotating magnetic field in the stator to turn the rotor and stator at the same rate. Like DC motors, these are permanent-magnet synchronous motors, or PMSMs, that rely upon magnets built into the rotor. AC models specifically use electromagnets and rely on an integrated power inverter, rectifier, and sensor.

Issues connecting to moving armature are avoided by using a fixed one with permanent magnets in the rotor. The lack of brushes in these motors also increases their lifespans, makes them cleaner and quieter, and reduces wear and tear. Potential problems with centrifugal forces are reduced by avoiding windings on the rotor and eliminating the need for active cooling.

4.3 Worm Gear Shaft

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power. Worm Gear shaft is used to push the mortar toward the nozzle through the Hose pipe. It is connected to the AC-motor through a universal joint.

Our designed shaft is 30-inches long having 11 threads with thread angle of 30° . OD=6inches and smaller dia of shaft=4inches.

The torque for the shaft delivered from an electrical motor producing 3hp at speed 1500 rpm can be calculated

$$T = \frac{hp (63,025)}{n}$$

Where hp is the horse power

N is the number of revolution

$$T = 126.05 \text{ lbf in}$$

The bending force produced by gears or chains is equal to the net driving force given by

$$F = T/r$$

$$\text{So } F = 126.05 \text{ lbf in} / 3 \text{ in}$$

$$F = 42.01 \text{ lbf}$$

4.4 Nozzle

A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe. A nozzle is often a pipe or tube of varying cross sectional area, and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them. In a nozzle, the velocity of fluid increases at the expense of its pressure energy. We have used Sand blasting nozzle, which is a special type of nozzle that can withstand the abrasiveness of the concrete mixture, and it can bear the thermal high resistance and the stresses applied by its particle on the nozzle walls.

4.5 Reciprocating Air Compressor

A reciprocating air compressor is a positive displacement compressor that uses a crankshaft-driven piston and cylinder to compress the air. A single-stage reciprocating piston compressor works by drawing the air into the cylinder where it is compressed in a single piston stroke of approximately 120 PSI and then sent to a storage tank. A two-stage compressor includes an additional step where the air is compressed by a second, smaller piston to a pressure of up to 175 PSI. Here Air compressor is use to give an extra push to the Mortar just before the opening of the nozzle at spray-Gun, to attain the maximum velocity.

Place of origin	xyz
Rendering Width	360 Sft/hr
Approximate weight	250kg-300kg
Dimension(L*W*H)	1350*440*800
Voltage	220V-380V (50HZ)
Hopper Capacity	78L
Conveying Height	10mm-12mm
Motor Power	3HP
Nozzle Dia	6mm

Application	Construction
Delivery pressure	8-bar
Compressor capacity	150L/hr, 8-bar
Hose DIA	32mm

5. CONCLUSIONS AND FUTURE RECOMMENDATIONS

In the manual plastering technique, the crucial factor is skilled labor because of which plastering has been done on the walls, but presently there is lack of skilled labors due to which it is very inconvenient to complete this process. The labor requires more time to finish the process which increases their wages and hence the total plastering or labor cost increases. Therefore, in this business plan we will provide a wall plastering machine named High Velocity Impact Plastering Machine, According to our estimate we can forecast it by investing approximately PKR 95000.

From the above discussion about old plastering techniques, problems in old plastering techniques, their downsides, background of the plastering method and the decided aim to be achieve following are some objective have been decided.

- This Machine will reduce the human work.
- It will reduce the total plastering time

A normal plasterer can plaster an Area of almost **60** square feet/hour, As our Aim is to cover the Area 360 square feet/hour,

So our machine is almost six times more efficient than a normal worker.

- It will be straight forward in construction and simple to control.
- Higher excellence of the plaster can acquire.
- It will be move horizontally from to other place. So that it will be portable.
- It will assist to save labor cost.
- It will avoid wastages of the mortar, thus to save the cost.
- Machine cost will be less than existing machines.
- It can be control with the help of remote controller.

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