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Performance Evaluation of Hydraulic Ram Pump with Rain-Cum-Roof Water Harvesting Structure in a Hilly Terrains of North East of India

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Abstract—*The people living in the hills face difficulties in raising crops to meet their daily needs due to lack of assured source of water and energy. The installation and maintenance of conventional pumping systems using diesel or gasoline or other forms of energy such as solar or electrical driven pumps are usually unaffordable for poor, remote communities living in the North East of India. To address this issue a field experiment was conducted in a hilly terrain of Assam University, Silchar to install a hydraulic ram pump with constructed polyethylene lined rain-cum-roof water harvesting structure (26500 L capacity and 2 m depth) and evaluate the pump performance for the on-site feasibility. A hydraulic ram pump (50 mm × 25.4 mm) was installed in the experimental site for the land slope of about 26.39 %, drive head of 4.05 m and inclined drive pipe length of 9 m and the performance of the ram pump (discharges and efficiencies) were evaluated with varying delivery heads. The highest discharge (35.395 L/min) was observed at 2 m head from the source (i.e. 1.5 times from the pump and the minimum discharge (3.563 L/min) was observed at 15 m head (i.e. 3.75 times from the pump). The efficiency of the ram pump was found highest (65.81%) at 9 m delivery head from pump or 5 m head from the source and lowest efficiency (17.17 %) at 15 m head from the source (i.e. 3.75 times from the pump). It was found feasible to lift water from the water source to 2-3.75 times from the level of pump for feeding overhead reservoir used for drip irrigation system in the hilly terrain Thus the hydraulic ram pump is the only alternative for the people living in the hilly terrain who are either inaccessible to energy sources like electricity and fuel and or unaffordable for it.*

Keywords: *Hydraulic ram pump, hilly terrain, performance evaluation, roof water harvesting.*

1. INTRODUCTION

Topographical constraints on hilly terrains (sources of water, energy and cost, etc.) turn down the application of an irrigation system for sustainable crop planning.

Lack of assured source of water in hilly terrain is a major challenge for crop production in higher altitudes. So, only the rainwater and stream (if available) could be harvested and utilized for crop planning and domestic use.Only the non-conventional source of energy is the possible source to irrigate such hilly and terraced areas and supply drinking water [1].Hydraulic ram pumps are water lifting devices with a time –tested technology may be one of the best solutions for the hilly terrain to address the issues of water supply and irrigation and energy .The main and unique advantage of hydraulic ram pumps is that it operates automatically and continuously with no other external source of energy that ensures low running cost, no harm to the environment (eco-friendly) and also simple, reliable and require minimal maintenance.

Since, lift irrigation system demands high investment in the hills and irrigation is a major hindrance to increase the productivity coupled with maintenance of terraces. So, hydraulic ram fed micro-irrigation system could be one alternative for sustainable agriculture in a hilly terrain.

Addressing multitude of socio-economic and physical problems of the hilly region, the present study envisages the scope for harvesting rain water or stream water resource and its utilization in crop production through hydraulic ram fed micro-irrigation in the terrace land of hilly terrain of North East, India.

2. MATERIALS AND METHODS

2.1 Exploration and installation of Ram Pump

One of the hillocks present at the Assam University Campus situated in the southern part of the Indian state of Assam is considered for the study site as shown in Fig. 1. The geographical position of Assam University is of latitude N 24˚41´ and longitude E 92º45´ with altitude 31.40 m above the sea level.The slope of the experimental site for installation of ram pump was found 26.39% where vertical fall or delivery head and inclined drive pipe length with horizontal distance between source and ram were found as 4.05, 9.0 and 8.02 m, respectively. So, in the present study the length the drive pipe was selected as 9.0 m.The Assam University located in Durgakona of Cachar district covers an area of 600 acres (2.4 km^2).

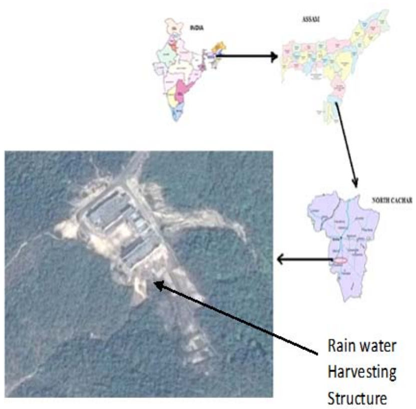

Fig. 1: Location of the study area.

It is necessary to measure the flow rate of water at the source to ensure whether, it is sufficient to operate the pump or not. In order to measure the flow rate of water at the source, a water meter was used in the drive pipe.

The flow rate of water at the source was calculated using the water meter installed in the drive pipe of 50mm diameter. The average flow rate was found to be 97.6 L/min (21.68 gallons per minute).

On the basis of the survey conducted in the experimental site, the various parameters such as the slope of the land, the supply and delivery drive head and the amount of flow of water from the source a hydraulic ram pump was fabricated for the experimental trial.A schematic view of the hydraulic ram pump and lay out of the experimental set up are shown in Fig. 2 and 3, respectively. The details of the specification of the ram pump is given in Table 1.

Fig. 2: A view of the fabricated hydraulic ram pump.

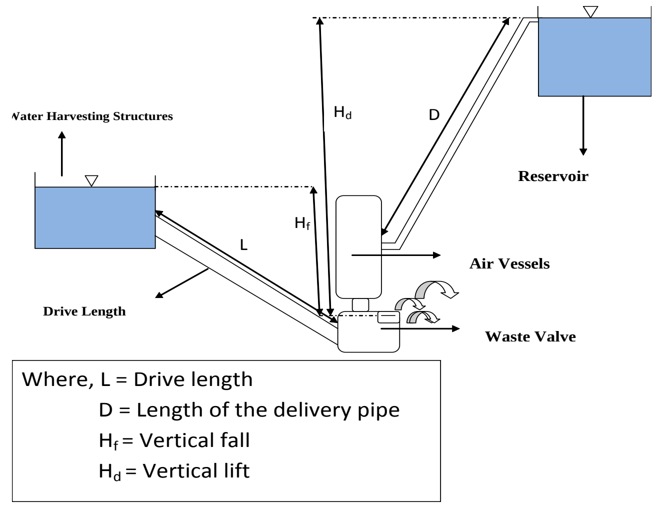

Fig. 3.Schematic diagram of a hydraulic ram pump setup.

Table 1: Specification of the selected hydraulic ram pump.

Sl. No.	Components	Size (mm)
1.	Inlet-Drive pipe	50.8
2.	Outlet delivery pipe	25.4
3.	Waste valve	71.12
4.	Air vessel	110.49
5.	Air vessel (length)	1041.4

2.2.Operation of Hydraulic Ram Pump

Hydraulic ram pump works in the principle of 'water hammer effect' or impulse. Ram Pumps have a cyclic pumping action that produces their characteristic beat during operation. The cycle can be divided into three phases such as acceleration, delivery and recoil.

(i) Acceleration - When the waste valve is open, water accelerates down the drive pipe and discharges through the open valve. As the flow increases it reaches a speed where the drag force is sufficient to start closing the valve. Once it has begun to move, the valve closes very quickly.

(ii)Delivery - As the waste valve slams shut, it stops the flow of water through it. The water that has been flowing in the drive pipe has considerable momentum which has to be dissipated. For a fraction of a second, the water in the body of the pump is compressed causing a large surge in pressure. This type of pressure rise is known as water hammer. As the pressure rises higher than that in the air chamber, it forces water through the delivery valve (a non-return valve). The delivery valve stays open until the water in the drive pipe has almost completely slowed and the pressure in the pump body drops below the delivery pressure. The delivery valve then closes, stopping any back flow from the air vessel into the pump and drive pipe.

(iii) Recoil - The remaining flow in the drive pipe recoils against the closed delivery valve - rather like a ball bouncing back. This causes the pressure in the body of the pump to drop low enough for the waste vale to reopen. The recoil also sucks a small amount of air in through the snifter valve. The air sits under the delivery valve until the next cycle when it is pumped with the delivery water into the air vessel. This ensures that the air vessel stays full of air. When the recoil energy is finished, water begins to accelerate down the drive pipe and out through the open waste valve, starting the cycle again. Throughout the cycle the pressure in the air vessel steadily forces water up the delivery pipe. The air vessel smoothens the pulsing in flow through the delivery valve into an even outflow up the delivery pipe. The pumping cycle happens very quickly, typically 40 to 120 times per minute. During each pumping cycle only a very small amount of water is pumped. However, with cycle after cycle continuing over 24 hours, a significant amount of water can be lifted. While the ram pump is operating, the water flowing out the waste valve splashes onto the floor or the pump house and is considered ‘waste' water.

2.3. Performance Evaluation of the Pump

Performance of the hydraulic ram pump was evaluated by estimating the efficiencies such as Rankine’s efficiency, D’Aubuissonefficiency and Efficiency by trade method. Efficiencies were evaluated using the observed pumped and waste flow i.e. water supplied by the source to the pump and pump head above the source of water for different sets of delivery heads.The discharge at delivery and waste valve was measured using the cylindrical tank and stop watch for different sets of delivery heads. Three efficiencies for different sets of delivery heads were estimated using the following equations:

Rankine’s efficiency is expressed as under:

$$E_{Rankine} = \frac{Q\times h}{(Q_w)\times H}\times 100 \quad (1)$$

D’Aubussion’s efficiency is expressed as:

$$E_{D'Aubussion} = \frac{Q\times H_d}{(Q+Qw)\times H}\times 100 \quad (2)$$

Efficiency of ram by trade method is expressed as:

$$E_{trade} = \frac{Q\times H_d}{(Q_s)\times H}\times 100 \quad (3)$$

Where, E= Efficiency of the hydram; $Q_s = (Q + Q_w)$ = water supplied by the source to the pump; Q=pumped flow, Lmin^{-1}; Q_w= Waste flow, Lmin^{-1}; h = pump head above the source, m; H = Supply head above the waste valve opening; H_d= (H +h) = Total head above the waste valve opening, m.

3. RESULTS AND DISCUSSION

3.1. Variation of Discharge with Delivery Heads

A number of experiments were carried out to find out the effect of discharge with the increase of delivery heads. The variations of discharge at delivery and waste valve with delivery heads are presented in Fig. 4.

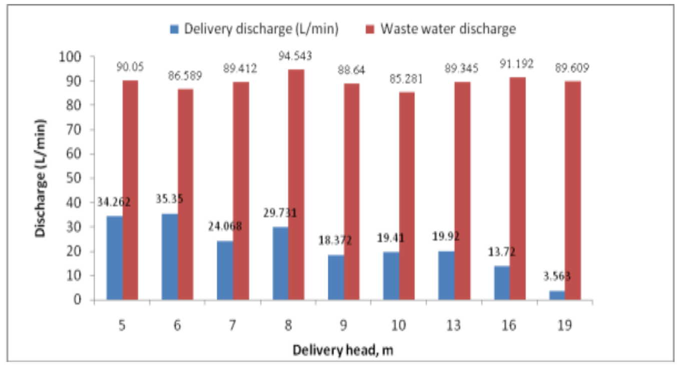

Fig. 4: Variation of waste water and delivery discharge with delivery heads.

Initially, the discharges at both the points were measured at an interval of 1m up to the height of 6 m from the level of source (i.e 10 m from the foundation of pump). Since, the variation of discharge was found almost same then the measurement interval was increased to 3 m to the delivery heads up to 15 m above the source of water. It has been observed that at closer head (1m) from the source the average delivery and waste valve discharge were found 34.26 and 90.05 Lmin^{-1}, respectively. During the experiments, the maximum delivery discharge was found 35.40 Lmin^{-1} at 2 m head from the source (i.e. 1.5 times from the pump).

3.2. Variation of Efficiency of Ram Pump

The variation of Trade’s Efficiency and Rankine’sEfficiency of the installed ram pump was estimated for each heads are presented in Fig. 5 and 6, respectively.It has been observed that at closer head (1m) from the source the average Trade’s efficiency was found to be 43.76%. During the experiments, the maximum efficiency was found 65.8% at 9 m head from the source (i.e. 2.25 times from the pump) which acceptable.

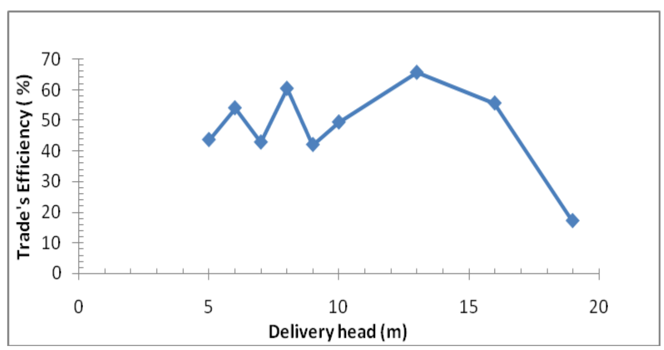

Fig. 5: Variation of efficiency with respect to Delivery head.

The minimum efficiency was found 17.17% at 15 m head from the source (i.e. 3.75 times from the pump) which is not feasible.

Fig. 6: Variation of Rankine's efficiency with respect to the delivery heads

However, the second maximum efficiency at 2 times head from the pump position was found 60.55% with less of 5.25% loss only. As it was observed that the hydraulic ram pump pumped the highest delivery discharge for the delivery head of 6 m but the highest efficiency was observed at delivery head of 13 m. So, the pump could be used to feed the storage reservoir at 13 m head from the pump position.

4. CONCLUSIONS

Based on the topographical constraints on hilly terrains (sources of water, energy and cost), turn down the application of an irrigation system for sustainable crop planning, the present study revealed that the selected hydraulic ram pump (50 mm × 25.4 mm (D/O) is feasible for feeding discharge (9 m above the water sources) and efficient (65.4%) to address the issue of water supply and irrigation and energy.

Hydraulic ram pump was found feasible to lift water from the source to 2-3.75 times from the level of pump for feeding overhead reservoir used for drip irrigation system in hilly terrain.The waste and delivery water supplied from the RHS could be utilized for crop planning in the terraces of hilly terrains round the year without shortage.

Thus, the hydraulic ram pump could be the only alternative for the people living in the hilly terrain who are either inaccessible to energy sources like electricity and fuel and or unaffordable for it. However, further details of feasibility study based on the crop water requirement and supply from the water source is needed foe sustainability of vegetables and other crops on the foot and hill top terraces of hilly terrain.

5. ACKNOWLEDGEMENTS

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