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ENERGY DISSIPATION OVER DIFFERENT FALL ANGLES THROUGH RECTANGULAR IRRIGATION CANAL; A PANACEA FOR SUSTAINABLE CROP PRODUCTION IN TROPICAL REGIONS.

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ABSTRACT
This study investigated flow energy dissipation over different fall angles. Physical models of various angles were produced Each model which represented a fall angle was inserted into a rectangular canal. Water was made to flow through the channel, the hydraulic parameters of flow over the model were measured and the energy dissipated were calculated. The research revealed that dissipated energy decreases by increasing flow rate. It also revealed that downstream depth decreases as fall angles decreases from 90^o downward, and that the rate of decrease reduces with reduction in fall angles. In addition, dissipated energy increases as fall angle reduces from 90^o downwards. Again, there is a vivid variation of the slope at angle 45^o. The slope continued uniformly till angle 40^o. The implication is that the optimum dissipated energy lies within the range of 40^o and 45^o fall angles. The dissipation of energy down stream will secure the irrigation canal and enhence food production. The result showed that the right fall angle at which irrigation channel produces optimum supply of water for maximum crop production lies within the range of 40^0 to 45^0. The implication of this is that, the adoption of the correct channel angles in constructing irrigation canal will promote the efficient utilization of irrigation water in crop production.

KEYWORDS: Irrigation, Energy Dissipation, Canal, Energy Dissipation, Food Production, Fall Angle.

INTRODUCTION

Irrigation is the act of supplying water to dry land by means of ditches or canals (Córcoles, De Juan, Ortega, Tarjuelo, and Moreno (2012). It is the artificial application of water to land to assist in the production of food and crops. Irrigation is used to assist in the growing of Agricultural crops, maintenance of landscape and revegetation of disturbed soils in dry areas and during periods of inadequate rainfall. There is an enormous potential in Nigeria through development of irrigation for higher yields, which could possibly be achieved by advances in bio-technology through development of higher producing, pest and drought resistant crops. However, agriculture is the largest water user; that is to say that the production of food requires adequate supply of water. The quantity of water required by plants could be made available through irrigation since Nigeria falls within the tropical zone. Again, Nigeria need to develop more vigorously the intermediate low cost water and soil conservation technologies which include water harvesting and soil tillage, mulching, terracing, and irrigation through canals to mention but few; these could significantly reduce the lack of water and lead to a substantial increase in yield. The adoption of this irrigation system will not only increase crop yield in the regions which heavily depend on rain fed Agriculture but will be play a critical role in sustaining food production in the tropics.

A canal is an artificial waterway constructed to convey water for irrigation (Novak, Maffat, and Narayanan, 1990). It is relatively a thin space, made of materials like concrete, mud, plastic and so on and of any shapes preferably rectangular or trapezoidal, through which fluid such as water flows at a gentle slope. Sporadically, sudden steep slopes exist in course of canal construction, may be due to changes of ground level. Most times, this leads to introduction of drops at points of change of ground level or fall to achieve construction objectives. Chanson and Toombes (1998) stated that at abrupt drop, open canal or channel flows are characterized by the presence of shock waves and substantial flow aeration. The waves generate force that endangers beds and sides of canal. The severity of the danger depends on the intensity of the force, the canal material of construction and the composition of the transporting debris that constitutes the fluvial system. It is generally accepted that fluvial systems perform work; against friction at boundary; against viscous shear and turbulence (internal friction); in transporting sediment load and wood debris; and in eroding the canal/channel bed (Knighton, 1984). The force or energy of flow needs to be dissipated to secure the canal.

Energy dissipation is the act of transforming mechanical energy of downward flowing water into thermal and acoustical energy. The problem of dissipating the energy of the flow that passes down a fall in a canal is important in agricultural and hydraulic engineering to reduce the erosion downstream of the structure. Various devices are designed in streambeds to reduce the kinetic energy of flowing waters to minimize their erosive potential on bed of channels.

Rajaratnam (1990) opined that flow in a stepped channel could be in either a jet or skimming flow. There is tendency that for a broad range of slopes, the shift from the jet flow to the skimming flow occurs when the ratio of critical depth to height of the slope is approximately equal to 0.8 (Chamani and Rajaratnam, 1999). They added that stepped spillways allow continuous dissipation of a considerable amount of the flow kinetic energy, such that the downstream stilling basin, where the residual energy is dissipated by hydraulic jump, can be largely reduced in dimensions. Rajaratnam also said that the cavitations risk along the spillway decreases significantly due to smaller flow velocities and the large air entertainment rate. According to Douglas, Gasiorek and Swaffield (1997), cavitations can cause serious problems, since the flow of liquid can sweep the cloud of bubbles into an area of higher pressure where the bubbles will collapse suddenly. Again, the problems of cavitations due to high flow velocities downstream of irrigation canal endanger plant growth in particular and food production in general. Adekanye, Otitolaiye and Opaluwa (2009) highlighted the problems of agriculture and food in Nigeria to include: low productivity and output, due to factors as limited across to input sources, the use of traditional technologies, irrigation problems and ineffective government and improvement policies. This research proffers solution to the cavitations problems along irrigation canal for bountiful food production. Various types of irrigation techniques differ in how the water obtained from the source is distributed within the field. In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little. To achieve this goal, the construction of irrigation canal using energy dissipation over different fall angles is conceived to be a panacea for sustainable crop production in the tropics.

Experiments on a moderately sized stepped spillway indicate that the energy loss due to the steps depends primarily on the ratio of critical depth to the height of the step as well as on the number of steps; and for small values of critical depth per step height near unity, or near the limit of skimming flow, the stepped surface is very effective in dissipating energy (Barani, Rahnama and Sohrabipoor, 2005). For higher values of the critical depth per step height, the effect of number of steps becomes appreciable, at a certain ratio of critical depth to height of step the relative energy loss increases with number of steps (Christodoulou, 1993). Chanson (1999) said that the energy dissipation characteristics of stepped channels were well known to ancient engineers. During the Renaissance period, Leonardo da Vinei realized that the more rapid the flow is, the more it wears away its channel: and if a waterfall 'is made in deep and wide steps, after the manner of stairs, the waters runoff can no longer descend with a blow of too great a force. Molnar and Ramirez (1998) studied the effects of energy dissipation on channel properties of a river network. They investigated the relationships between channel hydraulic geometry, flow velocity, channel bed slope, and stream flow condition in optimal river network. They argued that river networks develop average channel properties within certain ranges in order to attain constant rate of energy dissipation per unit channel area. Barani, Rahnama and Sohrabipoor (2005) used a physical wooden model of 21 steps to investigate energy dissipation of flow over stepped spillways of different step shapes. They showed that energy dissipation of flow on end sill and inclined stepped spillways are more than the plain one; increasing the thickness of end sill or the adverse slope size increases the dissipation. They also revealed that inclined stepped spillway dissipated more energy than equivalent end sill type. In this study, physical models made of mud and cement mix and covered with mortar were prepared. The prepared physical models were inserted inside a rectangular canal one after another to intoduce a fall. This enabled the resercher to identify the best fall angle to dessipate the optimum energy downstream of the irrigation canal. Water was supplied into the rectagular channel by a tank with a control valve to regulate the flow rate. The hydraulic parameters of flow over the models were measured and the dissipated energies of flow were calculated. The experiment was repeated several times using various flow rates.

General equation:

Several parameters do affect energy dissipation over fall angles. Such parameters include the head of water above upstream bed (H), depth of flow over the angles (D), angle height perpendicular to the model slope ([h.sub.1]), flow mean velocity (V), general slope of the model (tg), density of water (r), dynamic viscosity of flow (µ) and gravity acceleration (g), it follows that:

$$F(E_1, E_0, E_L, H, D, h_1, V, r, tg, \mu, g) = 0 \quad (1)$$

Where;

E_1 is the flow energy at upstream, E_0 is the flow energy at the downstream, E_L is the dissipated energy between the flow energy at the upstream and downstream. Mathematically, E_L can be expressed as:

$$E_L = (E^1 - E_1) - (E^{11} - E_1) \quad (2)$$

Where:

E^1 is the flow energy downstream at a pure vertical angle (90^o) and E^{11} is the flow energy downstream at inclined angle ($0<E<90$). E means angle.

The percentage of dissipated energy is:

$$E_1\% = \frac{E_L}{E_1} \quad (3)$$

using dimensional analysis according to Yazdani (1998) it can be a function of:

$$E_1\% = f1\left(\frac{H}{h_1}, \frac{D}{h_1}, tg, \mathrm{Re}, Fr\right) \quad (4)$$

Where;

Fr is the Froude number and Re is the Reynolds number. The drag coefficent Cd can also affect the flow dissipated energy. Cd can be a function of:

$$Cd = f_2\left(\frac{D}{h_1}, tg, \mathrm{Re}\right) \quad (5)$$

So equation 4 can be rewritten as:

$$E_1\% = f_1\left(\frac{H}{h_1}, Cd\right) \quad (6)$$

However, Yazdani (1998) reported the equation of flow dissipated energy as:

$$E1\% = 104.33\left(\frac{H}{h_1}\right)^{-0.015} Cd^{0.054} \quad (7)$$

And

$$Cd = 3.285Re^{-0.013}Fr^{-2.021}(\frac{D}{h_1})^{0.015}(tg)^{0.547} \quad (8)$$

MATERIALS AND METHODS

This experiment was carried out using a rectangular canal of a mild slope. The canal was made of concrete with breadth dimension of 198 mm, a depth of 300 mm and a length of 8000 mm. Physical models made of mud and cement mix and covered with mortar was prepared. The mortar surface gave the model a surface with a very low roughness coefficent. Ten models were prepared, each represented a certain fall angle. The fall angles were 10°, 20°, 30°, 40°, 45°, 50°, 60°, 70°, 80° and 90°. The prepared physical models were inserted inside the channel one after another to intoduce a fall. Water was supplied into the canal by a tank with a control valve to regulate the flow rate. The hydraulic parameters of flow over the models were measured and the dissipated energies of flow were calculated. The experiment was repeated several times using various flow rates.

RESULTS AND DISCUSSIONS

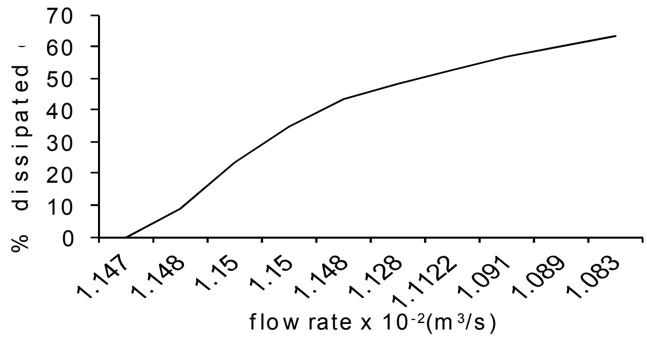

FIGURE 1: Percentage dissipated energy of flow against downstream flow rates of fall angles.

The percentage of dissipated energy of flow over different fall angles was plotted as a function of downstream flow rate of the angles on figure 1. The figure showed that dissipated energy increases as fall angle reduces from 90° downwards. Again, there is a vivid variation of the slope at angle 45°. The slope continued uniformly till angle 40°. The finding is that the optimum dissipated energy lies within the range of 40° and 45° fall angles. This is in line with the findings of Barani, Rahnama and Sohrabipoor (2005) who investigate energy dissipation of flow over stepped spillways of different step shapes and discovered that inclined stepped spillway dissipated more energy than equivalent straight fall type.

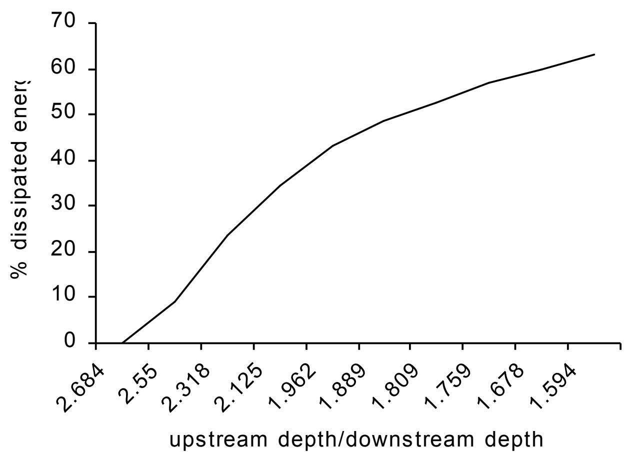

FIGURE 2: Percentage dissipated energy of flow against ratio of upstream depth and downstrean depth of fall angles.

Figure 2 showed the plot of the percentage of dissipated energy against the ratio of upstream depth and downstream depth of fall angles. The figure revealed that downstream depth decreases as fall angles decreases from 90^o downward. Again, the rate of decrease reduces with reduction in fall angles. The figure revealed that the reduction in depth was significant within the range of 40 to 45 degrees. This aswell reduces the velocity of flow to the point where the downstream velosity was peaceful with the bed and sides of the irrigation canal. The finding is in line with the work of Rajaratnam (1990) who found said that the cavitations risk along the spillway decreases significantly due to smaller flow velocities. The peace flow of water downstream will facilitate irrigation process and improve food production.

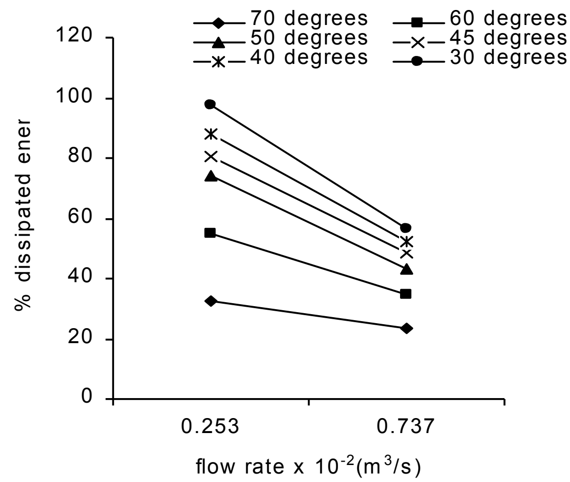

FIGURE3: Percentage dissipated energy of flow against upstream flow rates of fall angles.

The percentages of dissipated energy of flow over different fall angles were plotted as a function of upstream flow rate on figure 3. Two different flow rates were used. The figure showed that dissipated energy decreases by increasing flow rate. The piont here is to dissipate energy, therefore, the flow rate should be controlled and kept within the allowable limit to avoid high velocity flow that would cause cavitation. Here, the scope of the reseach did not cover the above stated effect.

CONCLUSION

The results of the experiments on energy dissipation over fall angles show that dissipated energy decreases by increasing flow rate. It also revealed that downstream depth decreases as fall angles decreases from 90^o downward, and that the rate of decrease reduces with reduction in fall angles. In addition, dissipated energy increases as fall angle reduces from 90^o downwards. Again, there is a vivid variation of the slope at angle 45^o. The slope continued uniformly till angle 40^o. The implication is that the optimum dissipated energy lies within the range of 40^o and 45^o fall angles. The dissipation of energy down stream will secure the irrigation canal and enhence food production.

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