Channel Incision Mitigation downstream of Intake Works

Conference Paper · September 2013

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Proceedings of 2013 IAHR Congress
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Channel Incision Mitigation downstream of Intake Works Case: Huachipa Diversion Dam

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ABSTRACT:

This research presents a methodology and results of the tasks performed on a mobile bed physical model whose main objective is to protect a downstream intake structure from local and general erosion. Huachipa Diversion Dam is located on the Rimac River, which is a steep river with a supercritical regime; on the right bank downstream from the intake presented a canyon formation due to erosion. To control the general erosion, a solution effective against this was the construction of a battery of rockfill or riprap sleepers, transverse structures that are placed buried in the bed of the stream, perpendicular to the direction of flow, from bank to bank and aims to slow the drop in elevation of the river bed. To local erosion control was used a riprap transition downstream from, stilling basin taking into account the fluctuating velocities and pressures generated macroturbulent flows. The model used in this research is a mobile bed model of scale 1/40, where longitudinal and transverse erosion and sedimentation processes are observed. The design flow is 580 m3 / s corresponding to a return period of 1000 years. The physical model was conducted in the National Hydraulics Laboratory of the National University of Engineering in Lima, Peru on a scale of 1/40 moving bed. The design of this proposal was based on the principles of tractive force and moments stability of a particle (Julien, 1995). Riprap sleepers were designed using the presented shear at the bottom of the channel or bed, built a protective riprap donwstream of diversion dam plus 4 sleepers. It had very good results for the general and regressive erosion control.

KEY WORDS: Sleepers, RipRap, incision, Steep River, Mobile Bed.

1 INTRODUCTION

Rivers have been major damage to humanity, but this is because it does not respect its plains, streams, is building a series of hydraulic works such as bridges, water intakes, etc. The intake for an investigation has a special problem because it is a structure designed with a supercritical flow steeply product has, the headworks building represents an alteration of normal runoff conditions, and hence be expected changes fluviomorfológicos important as erosion and sedimentation. Huachipa Diversion Dam is the headwork of a water supply project for the North of Lima. When using a mixed barrage, much of the flow passes through the barrage mobile during extreme events. This leads to a concentration of flows (flows greater than naturally occurring) downstream of the mobile barrage

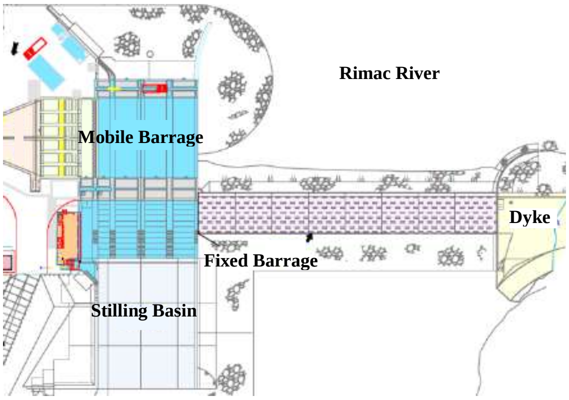

Figure 1. Huachipa Diversion Dam in Rímac River

The objective is essential that you protect the diversion dam downstream section from erosion with riprap structures arranged transversely and longitudinally in the channel. . Jimenez and Bateman (2006) note that the sleepers "are structures that are placed buried in the bed of the river course arranged perpendicular to the flow direction, from bank to bank and crown height just above the level of the bottom of the river. They often work together and their goal is to slow the descent of the bed height due to the general erosion ". Besides the need is debatable place a transition riprap bed downstream of the pool dissipating mobile barrage to disperse the flow across the width of the bed, avoiding incision. In this paper we describe the tests performed to protect the bed by several sections of the river. Huachipa Diversion dam is located on the river Rimac, a steep river with supercritical regime, being the slope of 3.23% in the Chosica - Pacific Ocean section The design flow is 580 m3 / s corresponding to a return period of 1000 years determined by probabilistic methods from instantaneous peak flows.

Figure 2. Incision in the right bank in the bed downstream of the stilling basin in Huachipa Diversion Dam

If the river bed is composed of erodible material such as sand, silt, gravel etc. that under natural conditions the flow path resists scattered over the entire bed, presumably to concentrate the flow over a range, there will be imbalances that lead to the incision. Measures such as distance, speed, straps, etc. be written first model measures and side brackets include measures that represent the prototype. Many of the phenomena that occur in nature and especially in the field of hydraulics, are so complex that it is not sufficient to treat only with mathematical, so it is advisable to resort to the use of experimental techniques. Mathematical models pose solutions idealized models, allowing significant simplifications, which in turn cause effects that should be evaluated by experimental tests. The simultaneous use of both research techniques yields better results since taking the mathematical model of the physical model results and vice versa, so that this interaction leads to approach the actual behavior of the phenomenon analyzed.

2 STUDY METHODS

It is important to clearly define that "erosion" means the loss or removal of bed material produced by an alteration of the equilibrium conditions of the river, according Vide (2000) notes that erosion in a channel is the descent of the bottom (or reverse the edges) as a consequence of dynamic phenomena of natural river or made by man. Overall erosion may distinguish local erosion, this first be explained by the action of a water flow simply characterized by a mean velocity. Erosion affects long channels and would be the only or primary on a straight channel, prismatic and without any singularity. Local bottom erosion is explained by the action of a complex stream, where a section of the stream (vertical, horizontal) require a two-dimensional description of the velocities, is presented as obstacles associated with singularities. Moreover, "balance" means that the profile of the bed is stable, the quantity of eroded particles is equal to the amount of sediment particles and dimensions remain unchanged background. Balance concept is expressed in the ratio of Lane (1955) proposed consider four variables: liquid flow, the solid volume, the slope (i) and the size of pellet (D) and arranged on the analogy of a scales:

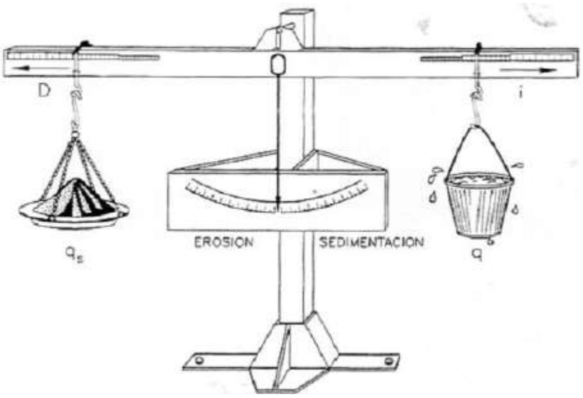

Figure 3. Lane Scales for understanding the equilibrium in Rivers

We can accept a battery of sleepers, always to resist, is a non-erodible in the river. When we say a cross protects implicitly acknowledge that the bed adjacent to the sleeper is kept fixed height, same of the sleeper. Thus we conclude that the cross prevents erosion (Figure 4). Now, this is only reasonable upstream of the sleeper. Despite this, Downstream will develop a work-induced effect called local erosion. But it also prevents the sleeper upstream only long-term erosion and shallow waters. In the long term, the longitudinal profile of a river with erodible would simply be lower.

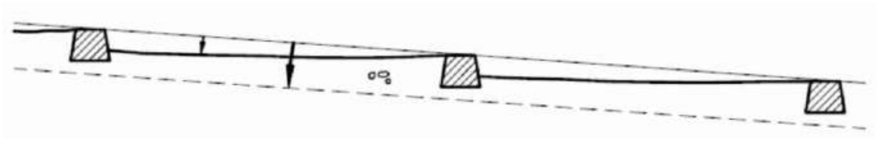

Figure 4. Sleepers' role for slow erosion process leading to the bottom the dashed line

The fixed points condition the decline, gradually being as salient points, while a jump appears downstream. This overall decline or erosion downstream is a direct threat to the sleeper and is also an indirect threat because the greatest slope of the waterfall local erosion worse. In short, the cross limits the extent of long-term erosion, rather than prevents it, but also threatened her. The slope between stretches limited by sleepers appears to be directly proportional to the distance between sleepers. This property reduces the efficiency of the sleepers put close together anyway because the jump will be higher than expected. The most influential variable erosion would reduce the distance between sleepers. This is also quite well in erosions discussed above, but taking into account the adverse effect indicated, so that the spacing of a series of sleepers becomes the most important engineering parameter (according to Figure 5), and also function in cost.

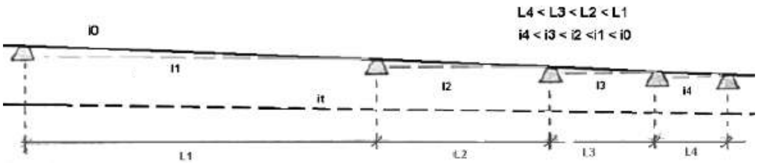

Figure 5. The river Slope changes as a result of sleepers

In these experiments it was found that both the temporal evolution of the phenomena as erosion downstream pit structure dependent hydraulic system and this in turn is influenced by the structure and especially the relative height between the base of the Naughty and dune crest generated immediately downstream of the pit. Other important conclusions were drawn from this study is that maximum erosion of the pit depends on the slope between sleepers and that there is a relationship between the scour hole and the downstream equilibrium profile. In the moving bed test was observed that the channel on the right bank began to erode. Product of the high levels of speed which intensified the shear and these at once dragged background particles. Protection channels built structures such as intakes are not described in full since they require detailed investigation. One method would be observing morphological phenomena in a physical model, analyzing what could happen and its similarity to reality. The various ways to protect the riverbed is: using vegetation sleepers riprap, riprap at the bottom of the channel, etc..

Figure 6. Critic Erosion presented at the Physical Model with unprotected bed (1000 Years Flow)

This is seen from the tests with the lowest flows, ie from 1.98 L/s (20 m^3/s). Subsequently, when the flow increases above 12.85 L/s (130 m^3/s), there is fixed barrage overflow and the water starts flowing on the left margin. Because the river bottom has fallen on the left, then the flow tends to concentrate on the channel deepened, further increasing the flow rate and resulting in a rapid decline. To test 29.65 L/s (300 m^3/s) without incorporating sediment, the channel drops to approximately 3.25 cm (1.3 m). From the proof of 46.45 l / s (470 m^3/s) presented velocities greater than 0.63 m/s (4 m/s) plus the bed down to rock bottom scour addition to test 470 m3/s, calculated daily mean values is in the order of 10 cm (4 m). Higher flow rates lead to lower even more. The pilot channel came to have an average width of 150 cm (60 m) and maximum erosion was 0.127 m (5.10 m) forming concentration induces shear stresses in part of the cross section, which extends in a direction downstream and could also extend upstream which may damage the diversion dam. In Figure 1, we can see that for the passage of peak flow far from when it started the diversion dam was 112 m^3/s of the riprap located downstream of the pool was displaced easily dissipating . Deep erosion was also observed in the right side due to the high velocities and fluctuating pressures generated in macroturbulentos flows.

Lopardo (2005) stresses the need to take into account the fluctuating flow parameters for an adequate definition of stable riprap protection in areas heavily fluctuating actions requested by downstream energy dissipators. It is for this reason that its methodology was followed to place a transition riprap downstream of the stilling basin in mobile barrage. For mobile bed essays with and without incorporation of sediment downstream of the diversion dam showed an incision in the right margin, forming a deep incision of the channel. Erosion may occur naturally with the current geological agent of erosion, or cause possible that man, as when the current is channeled, which results in an increased flow rate, increased shear stress or reducing sediment at a stretch, as occurs downstream of an intake. The bed can be lowered considerably by erosion.

2.1 Mathematical Model

To reassess the processes of erosion and sedimentation of the Rimac river bed, in the section where the work will be located in the diversion dam CCHE2D model was applied based on the balance of bed load transport of uniform material, numerically integrating the equations of unsteady flow and sediment transport in a non-coupled, using turbulent constitutive relations and applying a variant of the finite element method. The model solves the hydrodynamic equations and two-dimensional non-permanent water flow in the river, using turbulent constitutive relations and applying a variant of the finite element method, which is efficient element method. Based on the determined velocity field in the computational domain, the depth integrated flow in the convection-diffusion equation for suspended sediment transport, and the continuity equation for sediment bottom trawl. A detailed description of the model is presented in the work of Duan and Wang (2002) and Zhang (2005). We used the average monthly flow hydrograph for the months of December to April period of years 1987-2007 for unsteady flow analysis and historical flows calculated statistically for analysis during extraordinary floods.

The Rimac river bed is characterized by the predominance of coarse materials with uniform sediments ranging from sand, gravel, stones, boulders and bolonería. The simulations of the temporal evolution of the channel bed were performed for scenarios without project and with project. The results of the simulations without project show an increase over time of the variation of the bed, concentration speeds, shear forces and erosion process predominantly locally in the bed downstream of the dam axis (Figure 10). In the project scenario simulations, the presence of the diversion dam within the bed substantially alters the velocity field and the process of the temporal evolution and natural river bed configuration. Upstream of the diversion dam, there is the sedimentation process, which transforms bed, reducing its hydraulic section. In downstream, take the results of these erosions. The temporal evolution of the variability of the longitudinal profile of the bed with project (5, 10, 15 and 20 years) localized areas of erosion has increased over time to reach to a depth of 1 m in 20 years. If we compare with the results of the overall scour calculated with conventional methods on the same stretch of the river Rimac, there is a scour depth of 4.5 m for a flood with return period of 1000 years (maximum flow rate of 580 m^3/s).

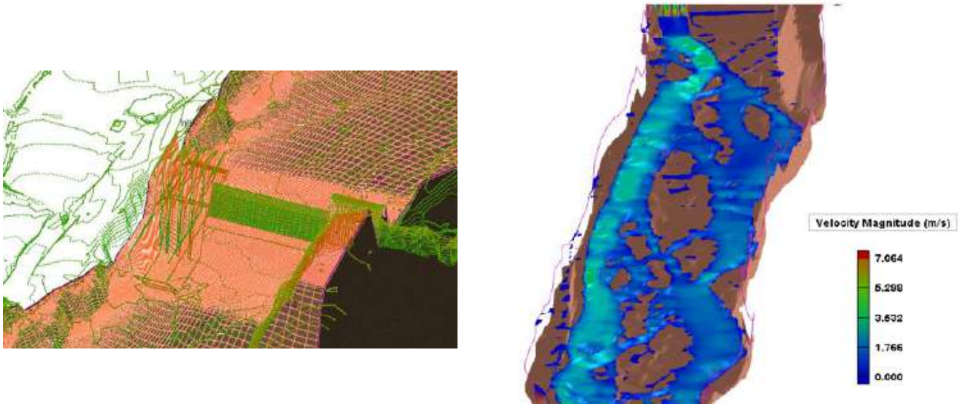

Figure 7. Finite Element Mesh and Velocity Concentrations on the right bank of Huachipa diversion dam (Unsteady flow with 20 years hydrograph)

3 EXPERIMENTATION

For general erosion control effectively it was built a series of riprap sleepers and a Riprap bed in transition (Figure 8). The model used in this research is a mobile bed model scale 1/40, in which you see the processes of erosion and sedimentation longitudinal and transverse. The banks and the plains of the river were modeled as rigid. Forward speeds downstream of the pool dissipating mobile barrage reached 5 m / s and the straps conjugates were presented in the model value of 2.40 m to 3 m, unprotected prototype measures in the National Hydraulics Laboratory, 2010. Once these parameters are defined diagram enters Lopardo proposed (2005) resulting in a stable diameter ds = 2.0 m. The calculated length was taken from the criteria used by the Corps of Engineers of the United States where the length of the rip rap is ten times the conjugated rod downstream. This calculation resulted in 30 m (from the progressive 0 +810 - 0 +840) generating a gradual transition riprap.

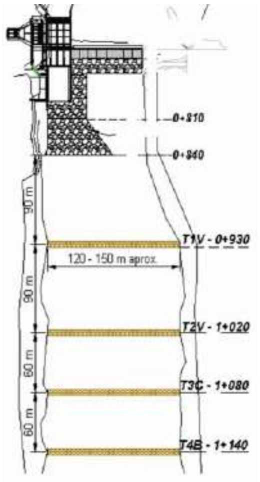

Figure 8. Proposal protection from bed incision downstream of Diversion Dam

Sleepers were designed taking into account the stability moment's method by Stevens and Simons (1971) and a better approach given by Julien (2010) which states that the threshold conditions occur when the moments of the hydrodynamic forces acting on single particle equilibrium resists moments strength. The ratio of resistance between the moments of motion is defined by two factors stability. Figure 9 illustrates forces acting on a particle loosely rests on a slope with an angle Θ_1 and angle Θ_0 downstream. Those are the lift force F_L, the drag force F_D, and the particle weight force F_s.

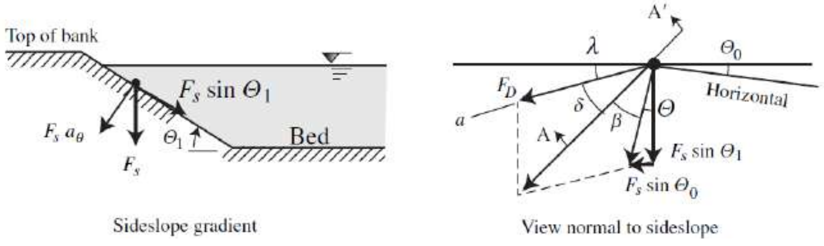

Figure 9 .Diagram of Forces in bed and particle by Julien (2010)

Provided the angle of inclination of the surface of water in the downstream direction is small, the driving force can be subtracted from the weight of the particle to give the submerged weight of the particle-FB FS = FW. The lift force is defined as the fluid force normal to the plane of the slope and the drag force is acting along the plane in the same direction as the velocity field around the particle.

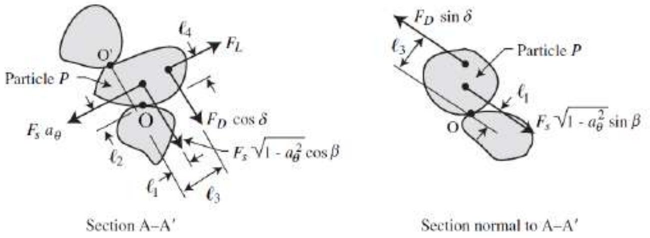

Figure 9. Particle study according to stability moment's method by Julien (2010)

The data were calculated using the physical model and some with computer models such as HEC-RAS and CCHE2D 3.1.1, resulting in a representative diameter of d = 1.45 m. Took a slope for sleepers 2% spacings lengths were 2.25 m (90 m), 1.5 m (60 m) and 1.5 m (60m).

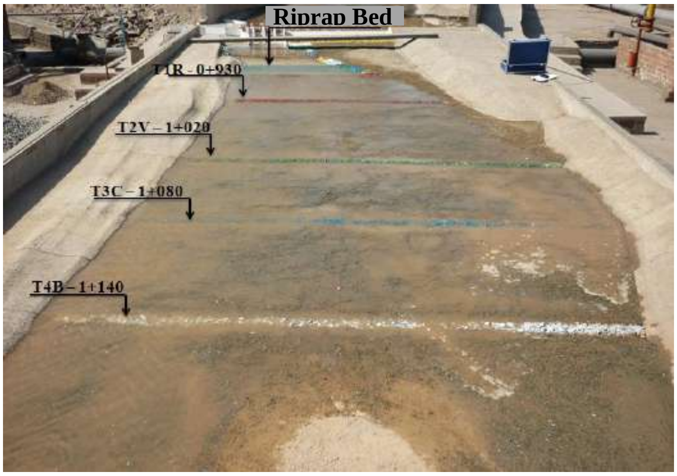

Figure 10 . Mobile Bed experimentation with RipRap transition and Sleepers

RESULTS AND DISCUSSION

The riprap protection sleepers yielded very good results for the overall erosion control downstream of the Intake Huachipa, maximum erosion was 3.125 cm (1.25 m). Sleepers and riprap transition controlled progressive and regressive erosion. The evolution of the bed slope was slow (Table 1). The slope between sections of sleepers were variable in different longitudinal profiles of river bed, noting that the longitudinal profiles of the right bank are the most noticeable where erosion and sedimentation continued to occur.

Discharge	Slope between sleepers			
	T1R-T2V	**T2V-T3C**	**T3C-T4B**	**T4B-Bed**
100 m^3/s	0.0159	0.0253	0.0096	0.00846
180 m^3/s	0.0246	0.0115	0.00910	0.0137
300 m^3/s	0.0178	0.0161	0.0114	0.0154
470 m^3/s	0.0323	0.00577	0.0137	0.0400
580 m^3/s	0.0208	0.00484	0.0169	0.5900

In the riprap transition movement was detected with 29.65 l/s (300 m^3/s). In 0 +850 the maximum erosion occurred was 2.5 cm (1m in the river). Among the T1R-T2V section the slope varies from 1.59% to 3.23% due to movement of the crest (inflection point) of the scour hole. For the T2V-T3C section slope, decreased from 2.53% to 0.4%, this section was presented an average erosion of 1.5 cm (0.6 m)

For assay of 46.45 l/s (470 m3/s) was recorded an erosion of 0.852 cm (0.341 m in river), moving the material upstream of the T3C sleeper, generating sedimentation with a value of 0.63 (0.252 m in river). In the essay of 57.39 l/s (580 m3/s) was generated an erosion of 2.05 cm (0.821 m in river). In the section T3C-T4B slope was increased from 0.96% to 1.69%. Froude numbers recorded ranged from 0.8 to 4.2. The T4B presented an average Froude number of 4.0. All essays showed a supercritical regime. On the right bank and left bank (1 +020 to front) struts presented varied from 4.25 cm (1.70 m) to 8.25 cm (3.30 m) and in the central part of the channel was 1.4 cm (0.56 m). In all essays the erosion length of T1R, changed from 16.80 cm (6.72 m) to assays of 9.88 l / s to 129.9 cm (51. 98 m).

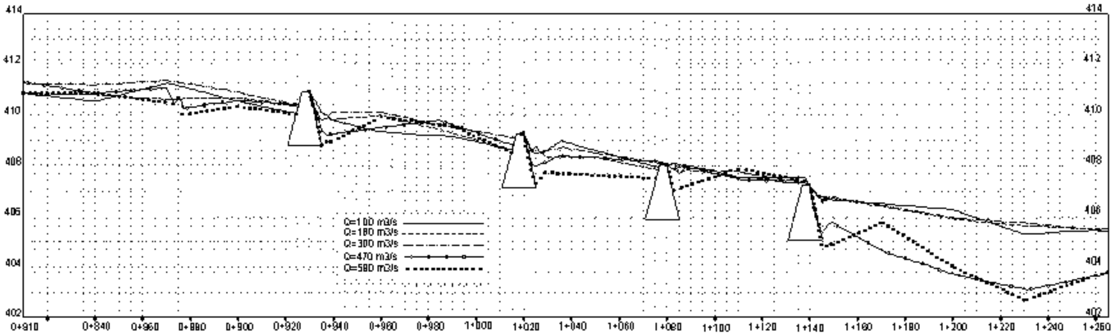

Figure 11. Longitudinal profile evolution from progressive 0 +800 - 1 +280 on the right bank

For 46.45 l/s essays after this length was decreased to 69.1 cm (27.46 m) with flow rate of 57.39 l/s (580 m^3/s) generating a maximum erosion pit 2.98 cm (1.192 m). In the T2V the scour hole length was swinging from a length of 35.6 cm (14.24 m), 19.67 cm (7.87 m), 36.95 cm (14.78 m), 34.07 cm (13.63 m), 19.1 cm (7.64 m) to flow tested five respectively, the maximum erosion pit was 3,195 cm (1,278 m). T3C in pit length was 22.97 cm (9.19 m) length was then almost zero for 46.45 l/s essays (470 m^3/s) presenting a very small scour hole 0.825 cm (0.330 m). For assay of 57.39 l/s (580m m^3/s) of the pit length was 75.25 cm (30.10 m) and the erosion was 2,465 cm (0.986 m). For T4B pit length was from 17.875 cm (7.15 m) to 77.25 cm (30.90 m) and erosions ranged from 1.397 cm (0.559 m) to 5.775 inches (2.31 m). RipRap transition had varied speeds for the five flow tested. The maximum speed was 0.591 m/s (3.74 m/s).

CONCLUSIONS

With the study showed that the sleeper can effectively act as a fixed point of the river profile, controlling upstream background levels in long-term evolution. A load downstream riprap transition of moving barrage dissipating pool, this leads to flow out or scattering across the width of the river without producing an incision on the runway. These should be designed castled taking into account the high speeds and fluctuating pressures generated in macroturbulentos flows. In the results of the physical model is found that good results are obtained with the scale used and there would scale effects.

Sleepers bed flush with much better performance that overhung a small crown. This naughty (T3C-1 +080) had no local erosion nor wavy flow was observed. For assay of 57.39 l/s (580 m^3/s) newly formed small significant scour hole, generating a small local erosion downstream. A battery is required (castled sleepers set) to control the general erosion in its entirety. The T4B for trials of 46.45 l / s and 57.39 l/s (470 m^3/s and 580 m^3/s) encañonamiento formed a small width and high local scour depth. Downstream of the sleepers with a small crown is a jump excelled. This decline or erosion downstream is a direct threat to the foundation of the cross would produce erosion pits of considerable magnitude, in depth and breadth. The shape of the sleeper if stability influences also castled guides the flow to take a tour of the angle of incidence of the jet. With the length between sleeper (1 +020-1 +080, 1 +080-1 +140) to half the width of the channel (60 m, measured in the prototype) occurred compared with slopes less range (0 + 930-1 +020) which gave two-thirds the length of the channel width (90 m). The sleepers did not show complete collapse despite being tested at a rate millennial instant. Besides incorporating testing without sediment were used to measure the maximum local and general erosion.

ACKNOWLEDGEMENTS

The study is supported by Hydraulics National Laboratory in Lima.

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