Impact Buried Plate as Scour Countermeasure Downstream of Hydraulic Jump in Open Channels

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A I n eat **scour downstream b¡'drau** iic **Atm cture** clue *to* **free hydraulic tump is** one **of the main interests of researchers where it** can **cause huge damage** o r **collapse for hydraulic structures. Many studies have applied** tn study the **maximum depth of** scour **and to develop** nov **counterm easure to control this pheno nienon. in this study. scour doz'nstream fixe** d **apron** by **using a** buried **plate as a eountermeasure was** stu **died.** many **experiments** were **conducted for Froude number ranged from 2.0** to **7.0 io** ss-hich a *plate w* **buried at different distances with different heights and thickness. .4lso. the effect of perforated plate** us **investigated. For runs which** buried **plate was installed,** tu'o **scour holes were formed behind and** in **l"ront of the plate. The dimensional analysis was** us ed **to drive the expres sion** that **link the different variables affected** on **the scour phenomenon.** It **was found that when the plate** was **buried at (0. 2 LB), the maximum scour depth upstream and doumstream the plate** (Ds1 **and** Ds2) **redu ced** by **33°A** anct 2S9b **resp actively compare** d **to the maxim** um **scour depth** *for* **no plate condition. Changing the thickness and heights** of **the buried plate was not** very **effective and clear.** Also. the **effect of perforated piate has negative res ults** on Ds1 **but positive results on Ds**2.

Kev Woiuds: Local Scour. Hydraulic jump. Fixed apron. Buried Ptate. Liaximum srour depth

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Introduction

Hydraulic jump causes iocal scorn- downstream hydraulic *structures* in mobile bed, which is one of the most complex problems affectin.• stability .Fixed apron behind sluic e gates may be threatened by soil particles erosion, iv!iere the fixed apron doivnstream hydraulic souctures is not sufficient length to allow a scour IioIe to form behind the apron [1,2].

Scour hole dimensions if they large, the hydrauiic structures foundation may not be covered leading to failure. For that many researchers studied the local scour downstream hjdrauli c structures. Rajaratnam and Aderibigbe (3] applied Iaboratory study to reduce scour behind vertical gates. In that lab study, they placed a screen on moi-abl e bed downstream gate. They indicated that scouring depth can be significantly reduced by placing a screen on the sand

bed. Different effect of spaced corrugated apron was ini-estigated Frith experimental study by Ali et at [4]. They concluded that by using this method scour deptii is reduced to 63.4℃c comparin• with original case. Khalili-Shajan and I'-arhoudi [5j ei aluated the effect of adi-erse stilling basin on local scour .They concluded that the size of scour hole for adverse case visas greater than the horizontal stifling basin and maximum scour depth minimize with increasing length and slope of stiilin basin.

Lin et aI [6] applied experiments on different Ages of ground sills to determine the best suitable spacing to protect the bed dois-nstream check dams. They found that bed doiimstream check dams can be protected by suitable condition of groimd sills\Vhen usin protection methods for structures, all the properties and inech anisms of scourin change depending on the type and location of the method used [7].

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The common methods to prevent and reñuce scour behind sluice gates *are* to use riprap stones or build a concrete apron. However, these methods may- be x-eiy expensive, no enough time to implement them and cause failure due to uplift pressure by erosion downstream the apron.

The sit is constructions is widely applied ago have sit ccessfuliy used to control erosion reduction and deflect flow. Sei-erai studies have proven that bed sills have many benefits and uses including increasing the *roug*hness of the bed, dissipating energy, reducing the inc an emoci9- and minimizing scour doismstre am of hydraulic jump [6]. Hamidifar et al. [8] applied experimental study to reduce scour doiimstre am fixed apron by using single bed silk with different heights. They concluded that maximum scour depth reduced up to 9S0i doupstream the apron.

Mason, Hager and Canepa [9,10] indicated that the scour phenomenon is affected by different factors such as dischar•e, upstream flow. I'-roude number and taii neater depth. Abdeihaleem [11] applied a group of semicircul ar baffle blocks to reduce scour downstream weir, many *con*fi *gurañons* for blocks *xx-ere* examined. He deduced that all arrangeine nts for used bIocks minimized the maximum depth of Scour.

Bate ' 112] evaluated the effect of vertical buried plates to control the scour around bridge piers. In his method embedded plates were installed so that the height of the plates was equal to the height of the bed. He found that scout hole dimensions decrease as a result of using plates. .'\bbaspour A, et al.. [13] studied the effect of single and double buried plates on scour downstream hydraulic jump with range for Froude number irom 4 to 9. In their laboratory study plates with slope an•les 50° and 90° with the. bed were buried at aiffezent distances from the apron with reverse and horizontai oed slopes. The results showed that by fiecre asing the an•Ie of the plate xx'itIi the bed the scour hepth decrease and the effect of double buried plates is better than single buried plate. Dey and Sarker [14] presented some. suggestions for determining the scour hole characteristic lengths tiirough a comprehensive study on erosion donmstream apron. Borhani [IS] applied expeiJmental study on the effect of buried pt ates with multiple anq•les on scour doismstream the •ate for low froude number (F*t* S 4.5). \Vang and Odgaard [16a studied preventing scour at brid•e peirs. They indicated that usin. vertical plates submerged in the bed leads to deflect of the how and very hiq•h control of erosion doi‹mstream hydraulic structures. Sciortiiio and Adduce [17a applied numerical and experimental investigation on scour downstream of bed sill. Khassat, et al., [18] ei aluated the effect of bed sill dovimstre am bridge pier on local scour and this led to reduce the maximum depth of scour by 25%.

Using riprap is one of the most popuiar methods to pi-otect the channel befi downstream of stillin• basin, it has many add antaqes such as bein v'ery durab le and ai-aiiable in most sites. Despite this, there are limits to the use of riprap as a countermeasure. U ostly Hydraulic structure ports, in case the underlying soil layer is lost due to phenomena of undermining, the riprap layer wiil be at risk of collapsin•. Melville and Lanchlan [19] pointed out that t!ie usin• of riprap is not sufficient scour protectio ii at brid•e piers. Omid â4H, et al., [20] applied experimental study to reduce the maximum scour depth caused by a horizontal jet issuing from a sluice gate opening doiimstream fixed apron. I'-or that, they used Evo types of countermeasures **(bed** sill and riprap). They found that in the case of using a bed siil the maximum scour depth iipstreain and downstream of the silk (Dsa and Dsi) is-as reduced bv 23% and 47°.i respectively, while in the case oJ usin riprap instead of the erodible. bed between the beñ sill and the fixed apron (Dst and Ds,) were reduced by 53*/o and 90*/a respectii-ely.

The main objectii-e of this study was to irn-estigate the efficiency of using buried plate as countermeasure doiiwtream fixed apron. A series of laboratoq' experts ental was carried out to measure the geometq of scour hole and evaiuatin.• the influence of different distances from fixed apron, plate thickness, plate height above fne original bed end effect of perforated plate on scour depth.

TTteoi **etical Study**

The Buckingham theory was applied to find the functional relati onship bem'een variables that shoism in Figure 1. The rna.ximum scour depth upstream and doiv'nsOeam the p!ate (De and Dst) could be expressed as folloix-s:

$$D_{S1}, D_{S2} = f(B, b, L_B, G, L_p, t_p, h_p, A_r, H_u, y_1, y_2, y_t, V_1, g, E_1, E_2, \rho, \mu, D_{50}, \rho_s, L_{s1}, L_{s2}, D_d, L_d) \quad (1)$$

By appl5'inp the Buckiii.=ham theory with selecting y-, vt, p as repeating i'ariab1es, Equation (1) can be written in dimensionless for m as

$$\frac{D_{s1}}{y_1}, \frac{D_{s2}}{y_1}, \frac{L_{s1}}{y_1}, \frac{L_{s2}}{y_1} = f(F_1, \frac{L}{\#e}, \frac{h}{L_p}, \frac{t}{L_p}, \frac{y_?}{y_1}, \frac{\Delta E}{E_1}, A,) \quad (2)$$

In which, Dst/y is the ref ative maximum scour deptii upstream the buried plate, Dss/yr is the relative m mum scour depth doismstre am rhe burieo plate, Psi/yr is the relative distance from the end of the apron to maximum scour depth upstve am the plate, Lst/yt is tiie relative distance from the end of the apron to maximum scour depth dois-nstre am the plate, F is the Frond e number at initial depth, Lt/La is the relative position of plate, ht/@ is the red ative height of plate, §/@ is the reiative thickness of plate, y_/yr is the relati ve depth of the hydraulic jump, H/Ei is the relatii-e energy loss and Ar is the relatii e area of perforated plate.

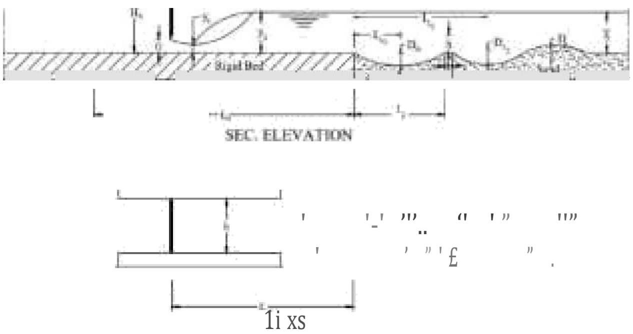

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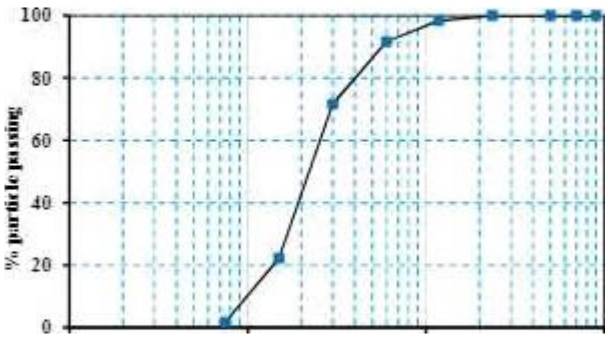
Figure 1: Definition stretch for the experimental model

Experimental Work

Experiments were conducted at t!ie Hydraulic and water Engineerinq• Laboratoq of the Faculty- of Engineering Za=azig University, Egypt A rectangular open channel flume 30cm ivnde, 15.6 cm lon• and 46.8 cm deep was used as displayed in Photo 1. A Perspe.x control sluice gate ve-ith thickness l0min is placed in the first third of the fliime. The removable bed composes of uniform natural sand with 10cm deep and 2.0 rn long formed downstream the fLxed apron. The median diameter dso of the soil is 0.25 mm as shoism in Figure 2 and geometrical standard deviation $(\sigma g=(d_{84}/d_{16})^{0.5})$ equal 2.04 where dscs, da*p and dash respectively are the sieve opening which passes 50%, 84% and 16%o of rhe grains. Flow depth and scour hole profile were measured by a point gauge ve ith an accuracy of *0.1mm. A plate of Perspex was embedded at different relative distances from the end of the fixed apron (,'L#=0.07, 0.14, 0.2 and 0.27). Different relative !ieights of the plate are considered in addition to the original ievel (ht/@ =0.07 and 0.13). The amia ble relati ve thickness were tested ()/Lt = 0.03, 0•07 id 0.2). The effect of perforated plate was Studied at different gate openin s (G=3, 4, 5, 6 and 7 CA). The ran•e of passing flows- achieved a range of Froude number from 2.0 to 7.0. The total number s of experimental runs were 70 runs. Each run lasted R'0 hours, is-hich is required to reach 85% of maximum scour

Photo 1 A general view of the dunne



'igure Z : **Particle size óistrúbutiozt for sedizneztt bed**

Results And Disdn sN ozs

Totally 70 rtins were conducted. The experiments *ix-ere* carried out in Evo phases, iv'ithout using a buried plate and with using a buried plate. The results of initial tests indicated that the shape of the scour hole differs comp!etely when using buried plate. The presence of the buried plate led to formation of Oslo scour holes with different properties: one upstream and the other dois'nstream of the plate. Tire iast was similar in shape to the scour hole formed iiñthout obstruction (the original case)

Effect of Buried Plate **Position on Scour** Hole **Characteristics**

To minimize the maximum scour riepth downsO-e am fixed apron, the effect of different buried plate positions (Lt/Lt=0.07, 0.14, 0.2 and 0.2 7) were studied. Figure 3 and Figure 4 showefi the relationship between the Froude number (F'-i) at initial depth and both of the relative scour depth upstream the plate (Dsi/vi) and the relative scour length from the end of the apron to maximum scour depth upstream rhe ptate (Lsi,'yi) respectively. lt has been noticed that there is a direct relationship beHveen the f'-1 and both of the relaÖve scour depth (Ds /y) and the re!aôve scour length (Lsd/y). It was obseri-ed that for all cases the maximum erosion occurred ou both sides of the flume. The results showed that using a buried plate with different i-elative distanœs (Lr /Ls) equal 0.t4, 0.2 and 0.27 leô to good resiûts in reducing scourin• upstreain the plate by 36%, 33% and 15s? respectively as observ-ed in fiigure 7. The best ref ative distance from the end of the fi.xed apnn was at (Lr/Ls=0.07) where the local scour upstream the plate reduc.ed by 50% compared to the. original case. Figure 4 illustrated that the relaÖve scour length (Lsi /ya) in case of using the buried plate was tess thaii the relative scour length in the case of the absence of the plate. Also, it ii as observed that irom Figure 4 the relaÖve lengtii of the maximum scour depth upstreani the plate from the apron (Lsd/y) decreases fi5- derreasing the r el ative plate distance fro m th e apron tb•), wh ere using a biiried plate at Le,'La equal 0.27, 0.2 , 0.14 and 0.07 reduced Lsi/yi by 17*/s, 43%,77•/c and 93% respectively as observed in Figure 8

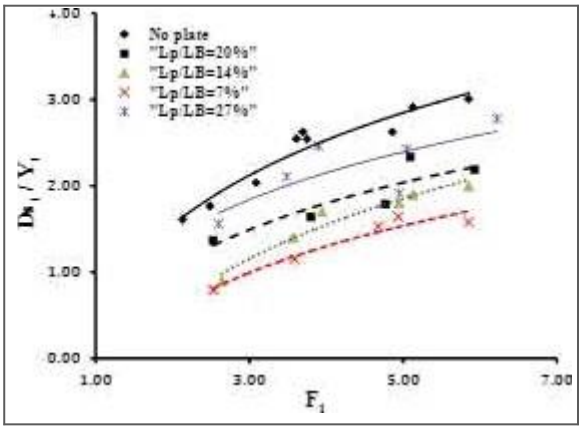


Figure 3 Relationship beUveen Dsi/yi and Fa for a buried plate at different riistances

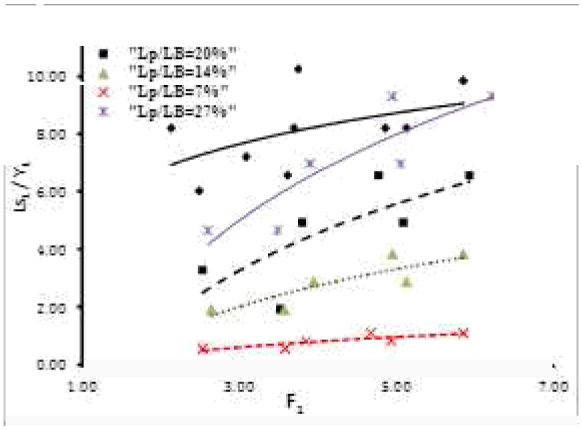


Figure 4 Relationship between Ls_1/y_1 and F_1 for a buried plate at different distances

Figure 5 illustrated the reiationship beHveen Fi arid the ref ative scour depth doivmstveam the plate (Dsz/yr). It has been noticed fliat the Dsi/ya increases by increasing Ft. It was found that using a buried plate with different relative distances (Lt/L#) equal 0.07, 0.14 and 0.20, reduced scouring downstream the plate by 11*%, 19fi3 ana 25% respectiv'ely as observed in Figure 7. The best relative distance firm *the* end of the fixed apron (Le/Ls) iv'as 0.27 which reduced the scour downstream the plate by 35% compared to no plate *c:ase.* Figure 6 illustrates the relationship beHveen Ft and the relative distance of the maximum scour depth downstream the plate from fne apron (Ls2/¿'£). It has been noticed that as Fi iiicr ease (Usr/yr) increases, at so (Lsi/yr) in cases of using plates was greater than the case or the absence of the plate. By increasing the distance of the plate from the apron, (Lsz/ya) increases, where (Ls2/j £) increased by (l2fi3, 27%, 43°/o and S3=/o) in the case of the presence of plates at (Lt,' LB 0.07, 0.14 , 0.2 and 0.27) respectively as obsein'ed in Figure 8.

lt was obseri ed that the maximum scour depth «hvays occurred doismstve am of the buried piate. In other words Ds is the maximum scour depth doivmoeam faxed apron. A ver' lar e scour of the soil doiimstream the buried plate may lead to the failure of the soil and consequently collapse the bui-ied plate due to the pressure of the soil from one side and this consfitutes a great danq•er to the fixed apron. By comparing the results of Dsa and Dsy 6
was found that using a buried plate at (Le /kz = 0.07) iv'as the best position to reduce scour upstream the plate Ds, by (50%), but it was the worst position to reduce scour doiimstream the plate Dsz by (11%). \Vhile, usin• a buried plate at (Le /Lz =0.2 7) was the best position to reduce scour downstream the plate Ds. by (3S%), but it was the worst position to reduce scour upstream the plate. Dst by (IS°/c). Therefore, using a buried plate at (Lr/Ls =0.2) was the optimum position to minimize the scour depth upstream and downstream the plate by (33% and 25%) respectiv'ely and achieve stability for the structure

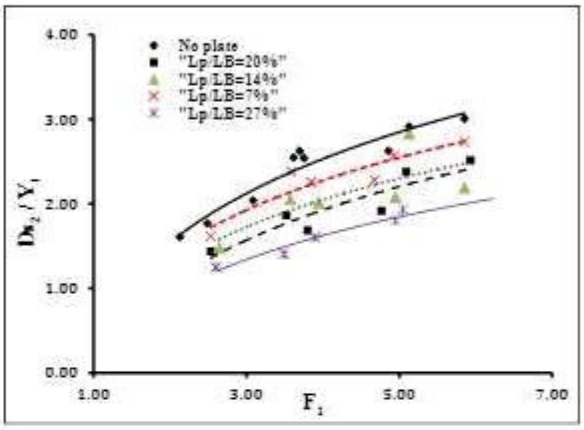


Figure S Relationship bed:'een Dsz /yi and Fa for a buried piate at different distances.

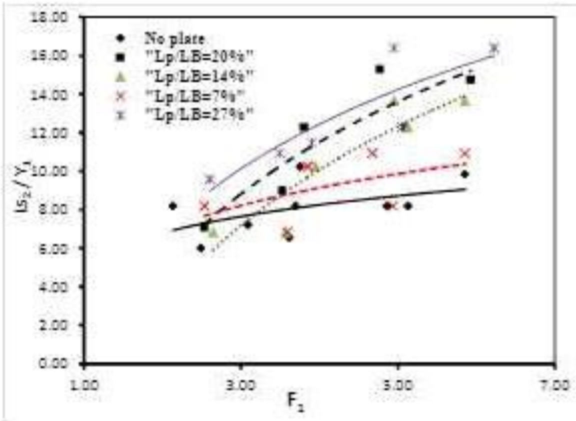
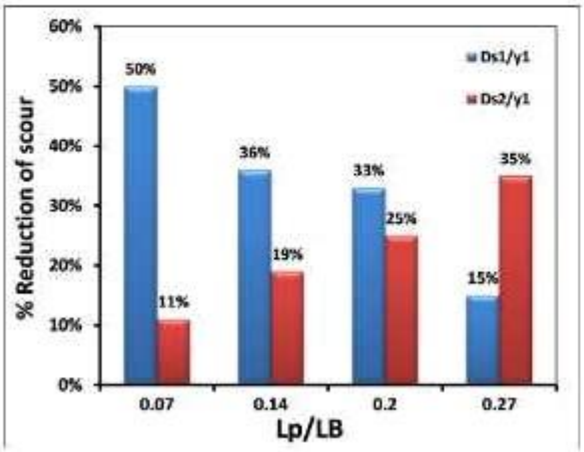
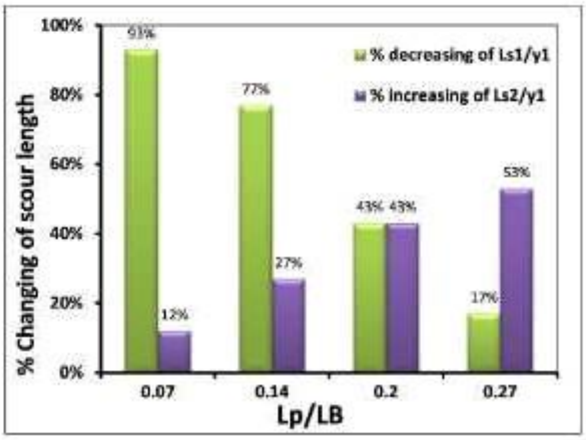


Figure 6 Relationship heaveen Ls /yt and F, for a buried plate at riifferent distances



Fivure 7 Reduction percenta=e or relatii'e scour depths for different position or plate Le,'Ls at Ft = 4.L5



Figui-e 8 changing percentage of ref ative scour hole lengths for diffei-ent position of plate Lr/Le at Fi=4.15

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Effect of Buried Plate Thickness on Scour Hole Characteristics

From the previoiis steps, a plate was ins*mlled at (Le/Ls =0.2) iiâ th a basic thickness of (te/Le =0.0/. One plate thickness te was chan•ed and the effect of this on scour ch ai-acteristics was investigated and to to- reducing the cost. Fi•ure 9 and Figure 10 sliois-ed the reiationship belt een F and both of the relativ'e scour deptii upstream the plate (Ds,/3-,) and the relative distance from the end of the apron to maxiıf ıum s cour depth upstream the plate U s /a›l respectively for different relative thickness (tr/1.e =0.03 and 0.2) of a plate at (Lt/£# =0.2). It mas been indirated that Dst/yt and Lst/y, increases by increasing Ft. .4s shorn in fig 9 and fig 10, the change of thickness has no noticeabl e effect on reducin both of the scour depth upstream the plate and the distance from the end of the epron to maximum scour depth upstream the plate. The plate used math the original thickness (tr/LP =0.07) reduced scourin• and distance by (33*/â and 43*ñ) while the thickness (te/Lr =0.03 and 0.2) reduced scourin by (34% and 32%) as obsern ed in I'-igure 13 and reduced the distant e by (40%c and 42%) respectively compared to the original case as observed in Figure t4. Figure 11 showed the relationship bed -een F and the relative scour depth downstream the p!ate (Ds„'yi) for different thinness (te/Le =0 03 ana 0.2) of a plate at (Lr,'l s =0.2). It was found that using a plate with the ori inal thickness (J/Lt =0.07) reduced the scour depth downstream the plate by (24°Zc) while the thickness (tr/be =0.03 and 0.2) reduced scouring b3- (15*/â and 27%) respectively coinpar eñ to the oriq•inal case tested in the present study. Figure 12 illustrated the relationship beHi-ee n Ft and the relative distance of the maximum scour depth doiimstrearn the plate from the apron (Lsi/yr) for different relative thickness (tp /hp-0.03 and 0.2) of a plate at (Lr/As =0.2). It was found that changing the thickness of the piate greatly affected on Lsz and rhe relative distance (Lsz /ja) increase by incre asin• the plate thickness up to (24%, 43,a and S7%) for (tr/Lr =0.03, 0.07 and 0.2) respectively. \Vhere we found there was no significant difference bens-een these ratios. This can be expr ained by that Dsi increases and Ds2 decreases by increasin• the thickness of the plate flue to the depth upstve am the plate receiving the entire how energy before moving to Dst, z'hich led to increases in Dsi and decry ase in Dsi and vice versa, where. Dsi decrease and Dsz increases by reducing the thickness of tire plate because the flow -ii•as rapidly tran sfer ited to Dsz before its fuii energy• iv'as dispensed in Dst. For that, installin• a p!ate at (Lt/Lt =0.2) with a origina' thickness (tt/Lt =0.07) was considered the best position to minimize the scour depth upstream and doiimstream the plate

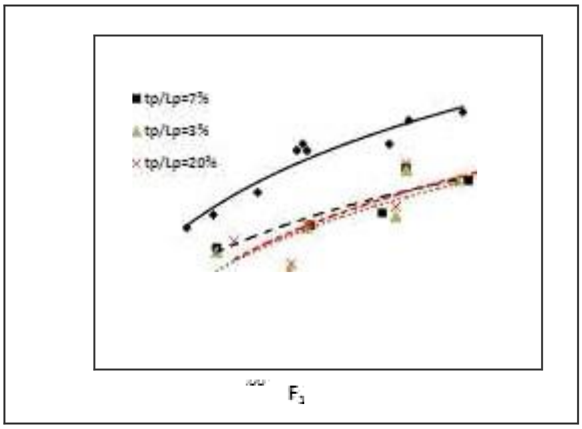
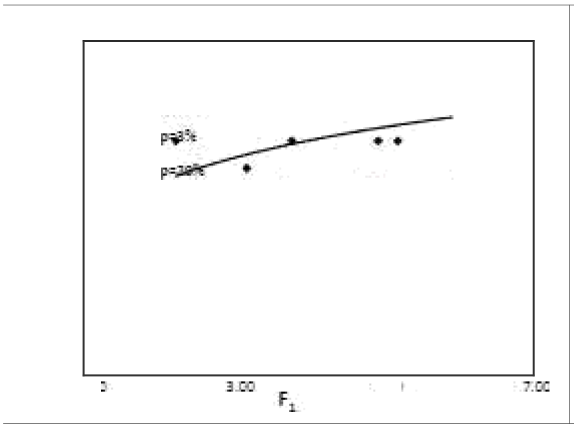


Figure 9 Relationship beDveen Ds /yt and F for a bui-ied plate for different thickness at Lr /La =20%



Figui-e 10 Relationshi p beHveen Ls /y and I'-t for a buried plate for different thickness at be/LB =200i

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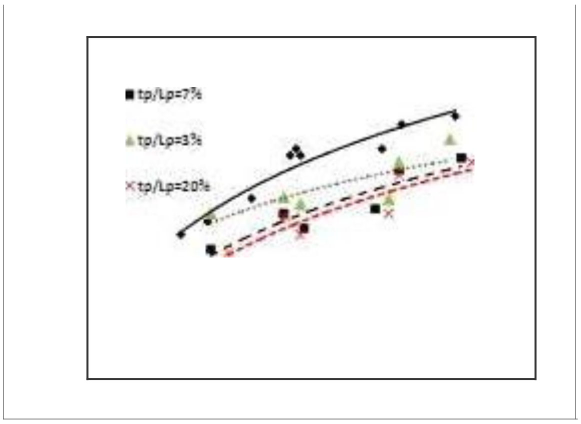


Figure 11 Relationship beHveen Dsz/5•i and Fa for a bui-ied plate for different thiclmess at Lr /Ls =20°,t

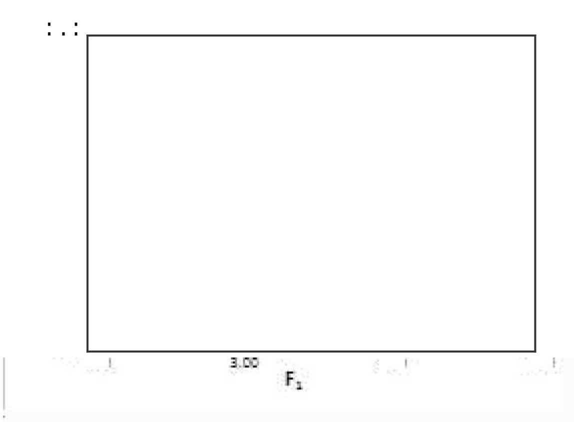


Figure 12 Relationship between Ls_2/y_1 and F_1 for a buried plate for different thickness at L_P/L_B =20%

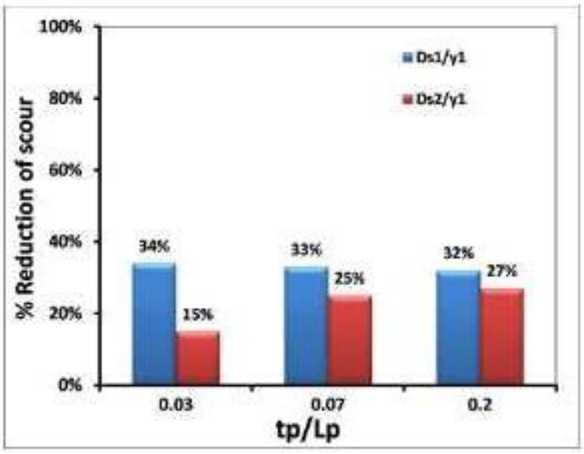


Figure 13 Reducñ on percentage of relative scour depths for different relative thickness of plate tr/Lr at Ft = 4.15

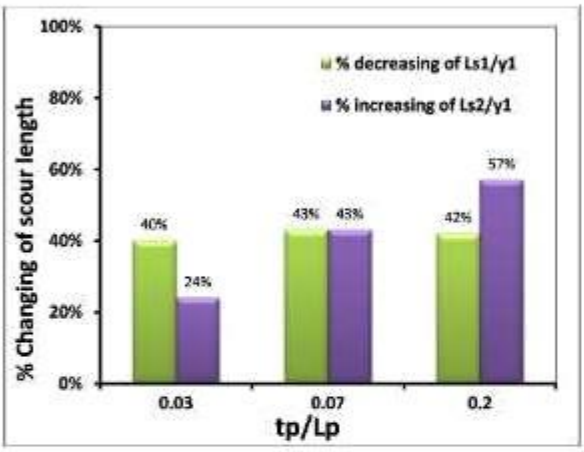


Figure 14 Changin• percentage of relatii e scour hole lengths for different relative thickness of plate te/Lp at Fi = 4.15

Effect of Buried Plate Height on Scour Hole Characteristics

The effect of plate hei.•ht ve here the plate is'as installed at (Le /La=0.2) with (te/Le=0.07) was studied. Figure 15 showed the relationship between Ft and the relative scour deptii upstream the plate (Dst/yt) for different relative plate heights (hp/hp =0.07 and 0.13). It was obsein ed that the. zero height plate case led to the largest reduction in scouring upstream the plate by (33%), while the relative height (lir/Le =0.07 and 0.13) were reduced Dst by (12% and 19%) respectively compared to the original case as observed in fiigure 19. Aiso, it was indicated that Dsa for (hi/Lr =0.07 and 0.13) was always greater than Dsi for the zero height plate. *This* can be explained by the action of overfiou' over the end of the apron. Visual observations indicated that the how field near the bed resembled a submersible jet with a recirculation area at the channel bed area. It was observed that when a plate is inserted at the split point of the back and forth flow at the bottom of channel, the plate may force the fomv'ard flu to move deeper into the channel thus deepening the bed Figure 16 illustrated the relationship beHveeri Fa and the relative distance from the end of the apron to maximum scour depth upstream the plate (Lst/yt) for different relative plate heights (hP/Le =0.07 and 0.13). It was observed that changing the height of the plate completely ineffective on Lsi compared to the zero height plate case. The zero heiq•ht plate case reduced Lsi (43%) while (ht/Lt =0.07 and 0.13) reduced Ls by (41%) for both compared to no plate case as observed in Figure 20. Figure 17 and Figure 18 showed the relationship beHveen Fi and both of the relative scour depth downstrem the plate (Dsz /yi) and the relative distance from the end of the apron to maximum scour depth doi›mstreain the plate (Lst/yr) respectively for different relative plate heights (lir /Lr =0.07 and 0.13). It was found that the zero height plate reduced Dsz by (25°A) but increased Lst by (43%), while the height (ht/Lt =0.07 and 0.13) were reduced Dsz by (28% and 34%) but increased Ls2 by (69% and 54%) respectively. As the height of the plate over the bed increases, the flow resistance increases and a smaller scour depth doismstream the plate was formed. Accordin• to the test data, using a plate at (LP/La =0.2) with thickness (te/Le =0.07) and zero height level decreased the volume of transported sediment and considered the best position to minimize the scour depth.

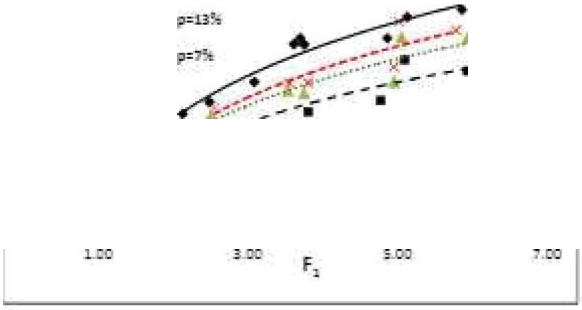


Figure 15 Relationship between D_{s1}/y_1 and F_1 for a buried plate for different heights at L_P/L_B =20%

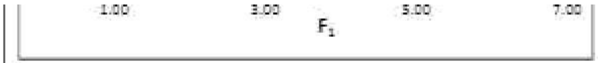
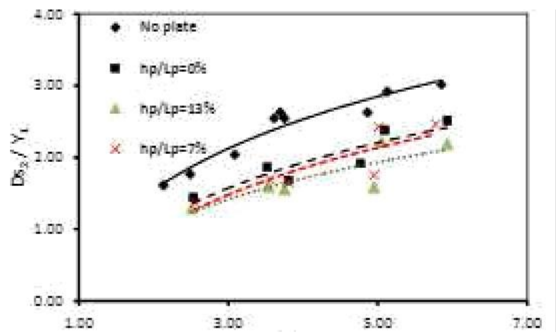
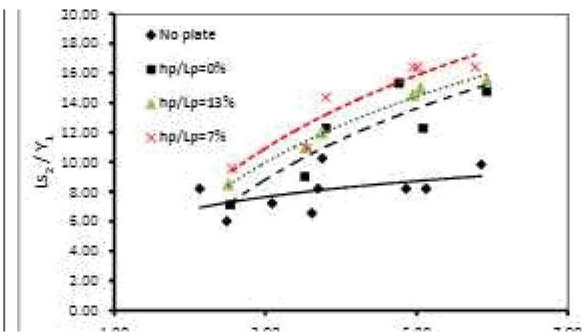


Figure 16 Relationship between L_{s1}/y_1 and F_1 for a buried plate for different heights at L_P/L_B =20%

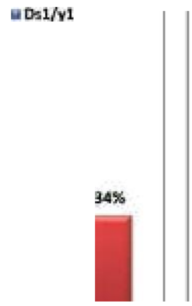




S 0

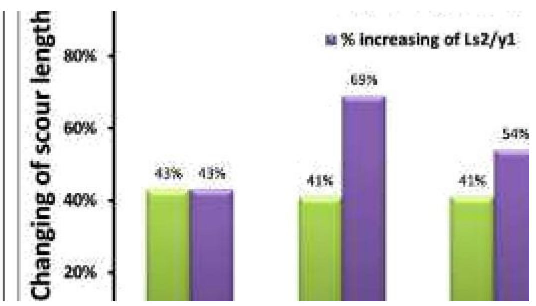
Fi•'are 17 Reiationship heaveen Dsz/yr and Fi for a buried p!ate foi- different her hts at Lt /Lt =20Uo

Figure 18 Relation ship beUveen 1sz/yr and Fi for a buried plate for different her hts at Lt/Lg =20°ñ



hp/Lp

figure 19 Reduction percentage of relative scour depths for different relative heig!its of plate te/ 1.e at Ft=4.15



a.oz a.¥*

hp/ip

Figure 20 Changing percentage of relative scour hole iengths for different relatii'e heights of plate tr,'Lr at I'-i = 4.IS

Effect Of Perforated Plate On Scour Hole Characteristics

The effect of perforated plate has been studied. This study included Hi-o parts. The first was a plate with a row of holes tin th Ar = 1.31\›é and the second is'as a screen with Ar = 28 °/o. Figure 21 sIioiv'ed the relationship beUs-een Ft and the relative scour depth upstream the pt ate. (Dsi /yi) for perforated plates. It i -as notable that the case of the solid plate gav'e the largest reduction for Dsi by (33%), white the perforated plate with a row of holes reduced Ds by (27%,.) and the screen gave the Iowest ab duction by t* 7%). This can be expr ained by the fact that the presence of the holes causes a rapid how of water and the sweep of the soil particles with it gyeatly through these holes. Tims led to very large soil erosion upsoeam the plate and thus a failure of the soil, which effected on the fixed apron and the stability of the structure. Figure 22 illustrated the relationsiii p beHve en Fi and the relative distance from the end of the apron to maximum scour depth upstream the plate (Lsi/yr) for perforated plates. It was observed that Lsi/ yr decrease by decreasing the relative area of perforated plates Ar, where the solid

plate reduced Ls, up to (43%) while plates o'ith (Ar=1.31% and 28%) reduced Lsa up to (40% and 36°Za) respectively. Figure 23 shows the ref ationship beoveen Fi and the relative scour depth downstream the plate (Ds /y) for pei-forated pt ate. It is-as notable. that the case of the solifi plate minimized Ds* by (2S%), z'hile the pei forated plate wk th a row' of holes and the screen minimized Ds, by (27% and 37%) respectii-ely as observed in Figure 25. Figure 24 illustrated the ref ationship beHveen Ft and the relative distance of the maximum scour depth downstream the plate from the apron (Lsz/ya). It was observed that the presence ofthe holes doesn't effect on Lsi at all compare to the solid plate. The solid p!ate increased Us• by (43%) white *grates* ten th (Ar = 1.31Wc and 28*/o) increased ks• up to (45% and 37%) respectively compared to no plate case as observed in Figure 26. The moi-ement of grains of sand with is-ater through the holes from upstream to downstream the plate leads to the accumulation of these grains doi‹mstream the plate thus reducin Ds*. And therefoi-e, a solid plate is the ideal choice to reduce scour upstream and downstream the plate and maintain stability of the strufire

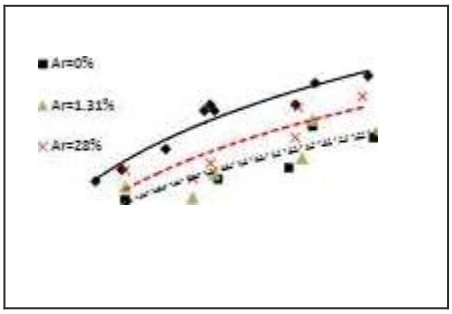


Figure 21 Relationship beds een Ds /yt and F for a buried plate for different Ar at Lr /LB =20%

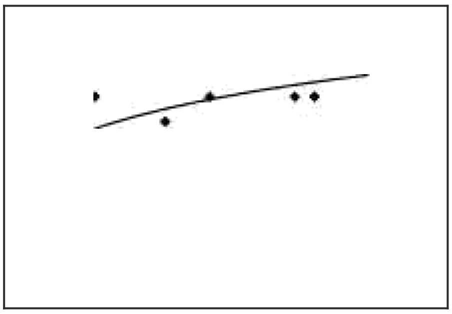


Figure 22 Relationship beHveen Ls /y and Ft for a buried plate for diffei-ent Ar at Lr /Lz =20%

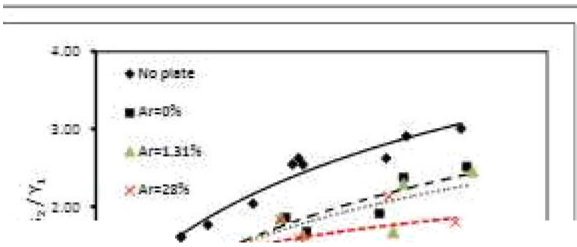


Figure 23 Relationship benx-een Dst/yt and F for a buried p!ate for different .Ar at Lr,/LB =20ic

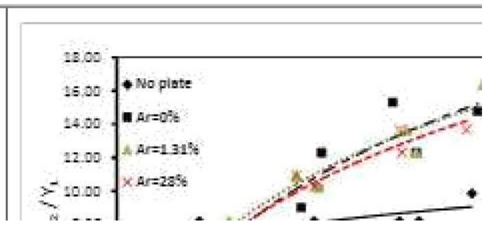


Figure 24 Relation ship bem-=en Ls›/y and I'- for a buried plate for different Ar at Lr /Lz =20₀ r

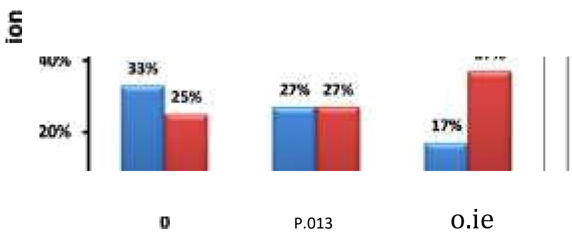
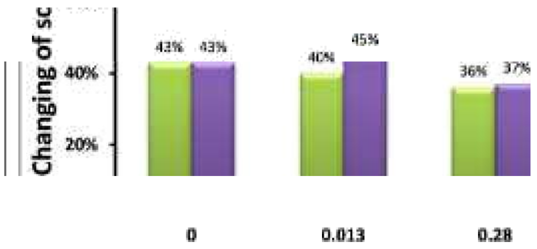


Figure 25 Reduction percentage or relative scour depths for different.4r at fi, = 4›15



rigire 26 Chan•ing pei-centage of relative scour hole lengths ior diffei ent.Ar at I'-i = 4.IS

S ?

Prediction of scour liole dinien sions

By usin= ilinitab pro•rain, the necessary statistical anal5-sis was do:ie to anaiyze the data. Based on the experimental results and using Minitab program, statistical ec,iiati ons have been proposed to predict the different scour diine nsions Dst/yp Ds›/yt. Ls /y, and Ls /y down.stream fixed apron in the case of usin• the plate The diffei-ent ñimensioi:s of the scour Dst/yt, Ds,;'yr, Lsa/ya and Ls /i'a downstream fixeo apron in the case of using the plate could b. estimated front the foIiowin equations

£quations	R°	Equation no.
$\frac{\circ}{y_1} = 0.8637t$ -!- $2.55\frac{h_p}{L_p}$ 3.065$\frac{}{L_v}$ +ñ001],	0.96	(*)
$\frac{D_{s2}}{y_1} = 0.4616F_1 - 1.95\frac{h_p}{L_p} + 0.586\frac{t.}{L/} - 1.148J$	0.96	(4)
$\frac{L_{s1}}{y_1} = 1.5181Ft - 1.97\frac{h}{L} - 20.5?^{t} + 0.75A$	0.90	(5)

$\frac{L_{s2}}{y_1} = 2.3921Fr_1 + 21.83\frac{h_p}{L_p} + 7.37\frac{t_p}{L_p} + 2.76A_r$	0.97	(6)

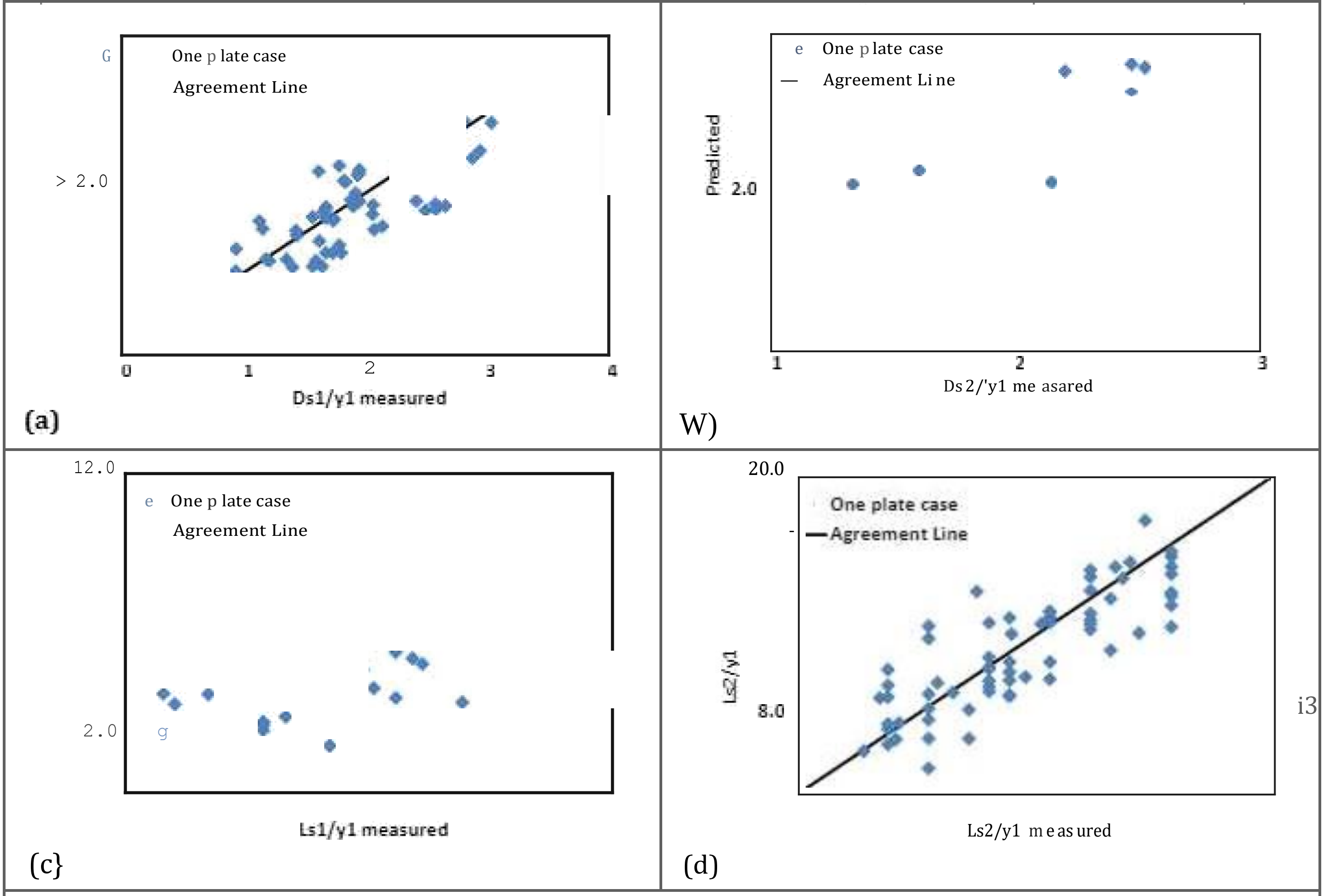


Figure 27 Comparsion beHveen the measured and predicted data for eqiiati on (3), (4), (5) and (6) respectively

LOIICiLlSIOIIS

In this paper, laboratory experiments were conducted to find nets methods to reduce !ocal scour dovimstream fLxed apron caused by hydraulic Jump doiimstre am s!uice gate.

A buried plate wzs proposed as a technique to protect an erodible bed doismstveam of the fixed apron. Variations in the scour dimensions for the scour hole were investigated for cases with and without buried plate with different variables for plate such (distances, thinness, heights and perforated plate). The main conclusions are:

1- The scour hole •eometry changes significantly when a buried plate is installed as counterme asure downstream the fixed apron. Also, Hi o holes are formed upsoearn to dor mstream the plate Frith maximum scour depth (Dsi and Ds°).

2- As ttie initial Froude number increase both of the relative scour depth (Ds,/yt and D_{s2}/y_1) and the i-elative scour distance (Lsi /yi and Lsi,'5 i) inci-eases.

3 Compared to tests without protective measures, the use of the plate at different distances from the fixed apron greatly effects on the different scour dimensions. Where we found by decreasing the distance of the plate from the fixed apron, Dsi and Lsi decreases, while Dsz and Usr increases.

4- The change of thickness has no noticeable effect on reducin• both of the scour depth upstream and doiinistream the p!ate and tire distance of the maximum scour depth upstream the plate from fLxed apron.

5- The impact of incre asinq• the height of the plate above the bed ied to a slig ht decrease in the scour depth dois-nstream the plate and the distance upstream the plate, but led to a huge increasing in the scour depth upstream the plate and the distance doismstream the plate.

6- The effect of perforated buried plate had negative results on Dsi but positive results on Ds*. fi'e i-ecommend tiyin• **perforated** plate with different heights aboi-e tire bea.

7- In this study, according to the test fiata the optimum position of the buried plate was found t*•/Ls=0.2) with (te/Le =0.07), equal to the her ht of the bed and solid plate which reauced different scour dimensions Dsi/yr, Dsi /vi and Lsi/jet by (33*/o, 25% and 43%s) respectively and increased Lsz/yr by (43%).

List of Dubois

B	The fluine iiñdth	b	The gate opening width
Dsi	The maximum scour depth upstream the plate	Dsz	Tire maximum srour depth doiimstream the plate
La	The fixed apron length from the gate openin=	Le	The buried plate **position measured** from the end of the fi.xed apron
G	The gate opening height	Ar	The relativ•e area of perforated plate
t_p	The buried plate thickness	yr	The initial depth of hydraulic jump
h_p	The buried pIate hei•Iit above the bed level	yz	The sequent depth of hydraulic jump
y_t	The tail water depth	Nu	The upstream is-ater depth
V	The mean i elocity at the initial depth	g	The gravitational acceleration
Ei	Specific energy at the initial water depth of a hydraulic jump	Ei	Specific ener ' at the sequent water depth of a hydrauli c jump
ΔE	Energy losses	Dso	The mean diameter of the sand base
Lst	The distance from the end of the fixed apron to Ds:	Ls	Time distance from the end of the fi.xsd apron to Dsc
Da	The maximum deposition	La	The distance from the end of the fixed apron to Da
ρ	The density of voter	ρ_s	The density of sand particles
μ	The dynamic viscosin-		

5 4

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