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JILID 2

EFFECT OF FLOOD PLAIN EMBANKMENTS ON CHANNEL SCOUR

ELIAS MOHD DEN
Universiti Teknologi Mara, Kampus Jengka,
26400 Bandar Jengka, Pahang,

ABSTRACT

A study has been conducted to investigate the effect of embankment constriction of a flood plain on localized scour in the main channel using a physical hydraulic model large enough to avoid scale effects of surface tension, gravitational affects and viscous forces. The physical river model considered is composed of mobile bed-channel filled with fine gravel (d_{50} = 2.5mm), flood plains with rigid bed and 70° skewed embankments. The study revealed that no scour occurred if the constriction on the flood plains or of embankments was less than 65% and in all cases the scouring started to occur when the velocity in the main channel reached a value of 0.62m/s which can be considered the threshold velocity of the fine gravel for the flow depth of 210mm. The results have also shown that the scour attained a maximum depth at a point where the velocity is maximum and there seems to be a definite relationship between maximum scoured depth, $(D+d_s)/D$ and the amount of constriction (m), provided $m \geq 70\%$.

Keywords: *Physical hydraulic-model, localized scour, dimensional analysis, embankment constriction, scoured depth and Profile.*

INTRODUCTION

Most watercourses experience erosion and deposition and consequent changing of bed levels with time as part of their natural lifecycle. Scouring means a lowering by erosion of the channel bed below an assumed natural level or approriate datum due to the erosive action of flowing water on the bed and banks of alluvial channels.

The design of a bridge over a river demands that attention should be paid not only to characteristics of river flowing beneath but also to the route location and potential traffic flow for example. In earlier times hydraulics problems were avoided by selecting bridge sites where channel were straight, banks were stable and a square crossing could be arranged. These policies have changed, (Neil,1973).

Changes in bridge location practices have resulted in the intrusion of road embankments into the flood plain where they too are going to be subjected to an erosion at time of overflowing and consequently have and effect on the scouring in the main channel. There is no unifying theory at present which would enable us to estimate with confidence the depth of bed scour due to channel constriction in the main channel or flood plain due to complexity of the problem. However geometry of constriction (such as width of channel and length of embankment) is one of the important dependent parameter besides parameters relating to fluid, flow and bed material.

LABORATARY STUDIES

Research work was undertaken in the Dept. of Civil Engineering, University of Strathclyde. The physical hydraulics model is a 10m long recirculating flume 2m wide and consisted of main channel 310mm wide by 340mm depth and on either side were flood plains 605mm wide, (fig.1). The bottom 180mm of main channel were filled with fine-gravel over 6.0m length. The upstream end of the flume has been tapered down to the flume base to overcome any turbulence and flow of 34 l/s in the system was provided by 3 phase electric pump through 6.5in PVC pipe.

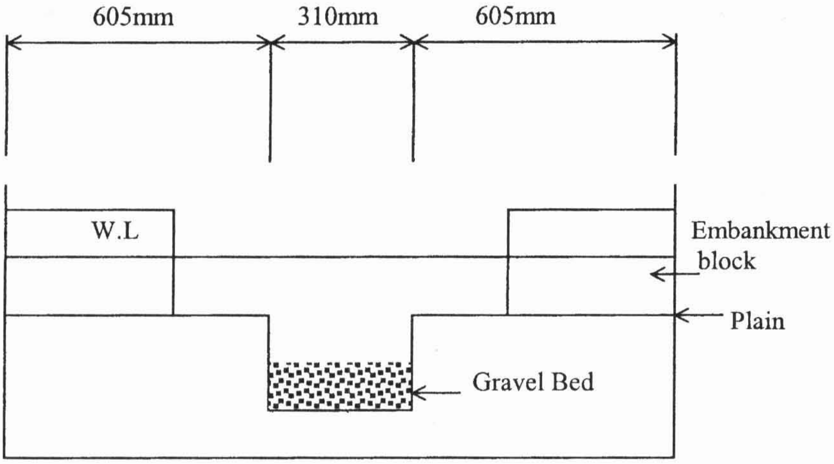

Figure 1: Section through constriction

The Embankment blocks were placed at approximately 2m from the downstream end. These blocks are 110mm high x 50mm wide.

OBJECTIVES OF INVESTIGATION

The main objective is to investigate the effect that the flood plain constriction has on the development of scouring. With the aid of experimental results it is hoped to get some picture of relationship between the percentage (%) of constriction and depth of scour at the downstream end. The location of the maximum scoured depth could also be located in relation to the amount of constricted section. The flow regime around and through the constricted section as well as flow velocities connected with the development of scour could also be studied.

The degree of constriction to the flood flow can be expressed as a percentage of area which can be passed, unimpeded through the constriction to the total flow area of the flood plains without constrictions. The amount of inclination of the embankment to the flood plain, has been choosen for two reasons;

(i) The effect on scouring. Due to the streamline nature of skewed embankment as θ is reduced, it is expected that there will be little scouring in the main channel because the effect of attacking current on the embankment will be less.

(ii) Reality of the real situation. It is very unlikely that the angle is less than 45°. Hence θ has been set to be 70°.

In carrying out the run, several assumptions have to be made,

(i) The flow upstream of embankment blocks is below the threshold velocity of the bed material.
(ii) Mean velocity obtained at 2/3 of flow depth.
(iii) Flow rate is constant.
(iv) Maximum scour occurs not in the middle of the main channel, but to one side of its centre, which is nearer to the lower side of the two embankment blocks where turbulence effect is greatest.

FRAMEWORK OF ANALYSIS OF SCOUR DEPTH

The flow in the vicinity of constricting structure is so complex that a complete analytical or numerical description of scour process is not possible. What is going to be considered here is the framework of the analysis of scour depth based on dimensional analysis on the assumption that the scour depth is dependent upon four variables.

(i) Variables describing geometry of channel and of embankment:

Width of flood plain	W
Width of main channel	B
Length of embankment	L
Angle of embankment	θ
Constriction ratio	m

(ii) Variables describing the flow:

Mean velocity	U
Depth of flow	D
Maximum scour depth	d_s

(iii) Variable describing the fluid:

Mass density of water	ρ
Dynamic viscosity of water	μ

(iv) Variables describing the sediment:

Median size	d_{50}
Standard deviation	σ_g
Density of bed material	ρ_s

If the maximum scour depth relative to water surface is taken as the dependent variable, then its depth is therefore a function of the following parameters.

$$(D + d_s) = f(W, B, L, \theta, U, \rho, \mu, d_{50}, \sigma_g, \rho_s)$$

A better representation of sediment and water mixture is $\gamma_s = g(\rho_s - \rho)$ i.e submerged specific weight of bed material. If μ is replaced by $v = \mu/\rho$ the equation becomes

$$(D + d_s) = f(W, B, L, \theta, U, \rho, v, d_{50}, \sigma_g, \gamma_s, \rho_s)$$

However because W, the settling of the sediment is a function of d_{50}, ρ, v and ρ_s one can substitute W in place of any of the previous four variables. Substituting W for v and selecting U, D and ρ as the repeating variables yields

$$\frac{(D+d_s)}{D}=f\left(\frac{W}{D},\frac{B}{D},\frac{L}{D},\theta,\frac{U}{(\Delta\gamma D/\rho)^{0.5}},\frac{U}{W},\frac{d_{50}}{D},\sigma_g,\frac{U}{(\gamma_s D/\rho)^{0.5}}\right)$$

With certain manipulations, permissible within theory of dimensional analysis, the equation can be written as

$$(D+d_s)= f\left(\frac{W}{D},\frac{B}{D},\frac{W-L}{D},\theta,\frac{U}{(gD)^{0.5}},C_D,\frac{d_{50}}{D},\frac{\gamma_s}{\gamma},\sigma_g\right)$$

In which γ_s and γ are specific weights of sediment and water respectively and C_D is the average drag coefficient of sediment defined as

$$C_D = \frac{4}{3}\left(\frac{\Delta\gamma_s d_{50}}{W^2\rho}\right)$$

Assuming further that W/D, B/D, d_{50}/D, C_D and and σ_g are of secondary importance and substituting $(W - L)/W = m$, the constriction ratio, following equation is obtained

$$\frac{(D+d_s)}{D} = f\left(m, \theta, \frac{U}{(gD)^{0.5}}\right)$$

In the investigation, θ is held constant at 70° , hence

$$\frac{(D+d_s)}{D} = f\left(m, \frac{U}{(gD)^{0.5}}\right)$$

Both Froude No. $[U/(gD)^{0.5}]$, and constriction ratio (m) are important parameters governing the maximum scour depth. In this experiment the variation of Froude No. on scouring is not going to be investigated. Hence $(D + d_s)/D = f(m)$, i.e a functional relationship of flood plain constriction on channel scour.

EXPERIMENTAL STAGE & MEASUREMENT

A number of trial runs were carried out so as to get the correct setting of flow rate, time of flow, velocity of attacking current and the scouring depths. A flow rate was set at 34 l/s and the velocities at the downstream end of the constricting blocks were found sufficient to initiate the particles bed movement.

There was a range of six constricting embankment blocks with constricting ratios, (m) of 50%, 65%, 74%, 83%, 92% and 100% respectively, the smallest of these did not have any measurable affect on the bed material.

The water level was filled up to 50mm depth of the embankment blocks and flow rate kept constant in all runs. It was left running for 24hrs to ensure that for all practical purposes the bed had reached a state of equilibrium.

Measurement of mean flow velocities was taken at approximately 2/3 of the flow depth using an ott current meter. The second were the scour depths together with the location of maximum scour depth. Measurements were taken every 10cm along the line of greatest scour depth of the scour area.

In order to show the flow pattern of the attacking current around the constriction a photographic device was adopted. These can be seen in figure 2, 3, and 4 for constriction of 100%, 74% and 65% respectively.

EXPERIMENTAL RESULT AND DISCUSSIONS

A summary of the results is given table 1 and 2.

Table 1: Scour depths (mm)

Y(cm)	Constriction (m)				
	100%	92%	83%	74%	65%
-10	6				
0	13	7			
10	18	16	6		
20	22.5	20	15		
30	23	22	19	6	
40	19	20	20.5	7	
50	10	9	19	11	5
60	6.5		14	14	6
70			9	17	8
80				14	9
90				13	6
Max.ds	24	22.5	21	17.5	9.5
Location(cm)	(3.9,27)	(3.8,33)	(3.4,45)	(2.7,73)	(1.8,82)

Table 2: Velocity profiles (m/s)

y(cm)	Constriction(m%)				
	100%	92%	83%	74%	65%
-70	0.38	0.38	0.37	0.38	0.36
-60	0.39	0.38	0.38	0.38	0.36
-50	0.41	0.39	0.38	0.39	0.38
-40	0.44	0.41	0.41	0.41	0.40
-30	0.48	0.43	0.42	0.43	0.42
-20	0.54	0.48	0.47	0.46	0.45
-10	0.61	0.54	0.53	0.51	0.48
0	0.68	0.62	0.60	0.55	0.52
10	0.72	0.67	0.64	0.58	0.55
20	0.74	0.72	0.68	0.62	0.61
30	0.74	0.73	0.70	0.64	0.61
40	0.73	0.73	0.71	0.66	0.62
50	0.73	0.72	0.71	0.67	0.63
60	0.72	0.72	0.69	0.68	0.64
70	0.71	0.71	0.68	0.68	0.64
80	0.68	0.68	0.67	0.67	0.64
90	0.66	0.65	0.65	0.66	0.63

Note: -ve values denote upstream end of embankment blocks

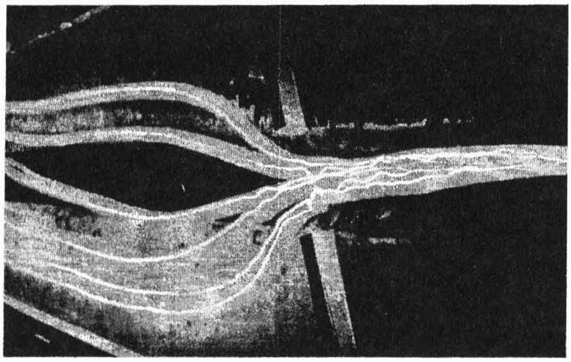

Figure 2: Flow pattern for m = 100%

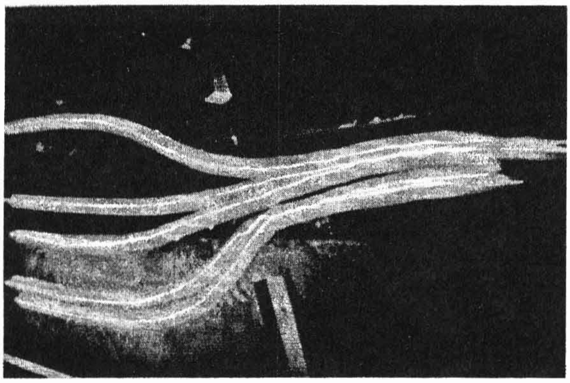

Figure 3: Flow pattern for m = 74%

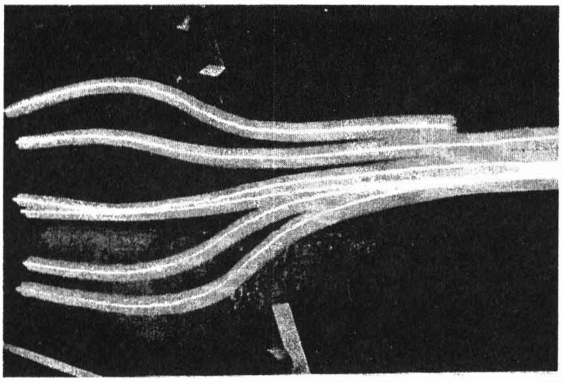

Figure 4: Flow pattern for m = 65%

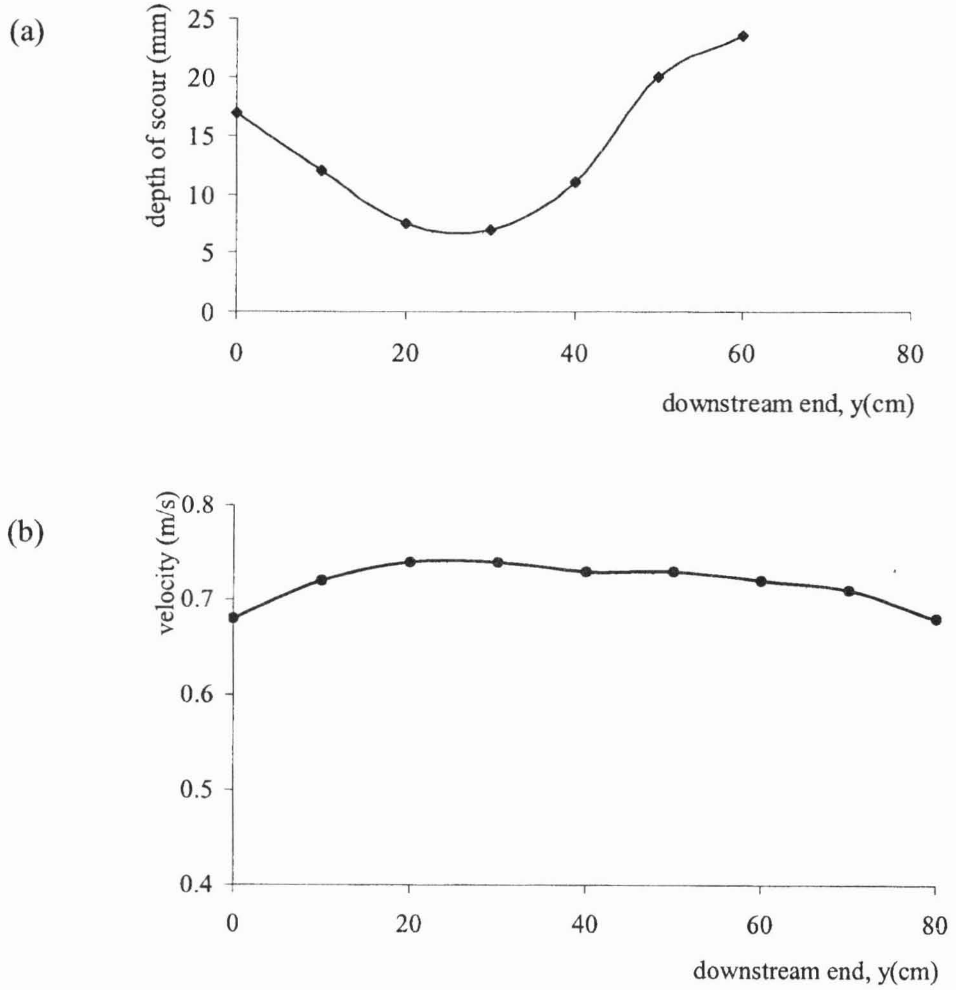

Figure 5: (a) Scoured profile for m = 100%
(b) Velocity profile for m = 100%

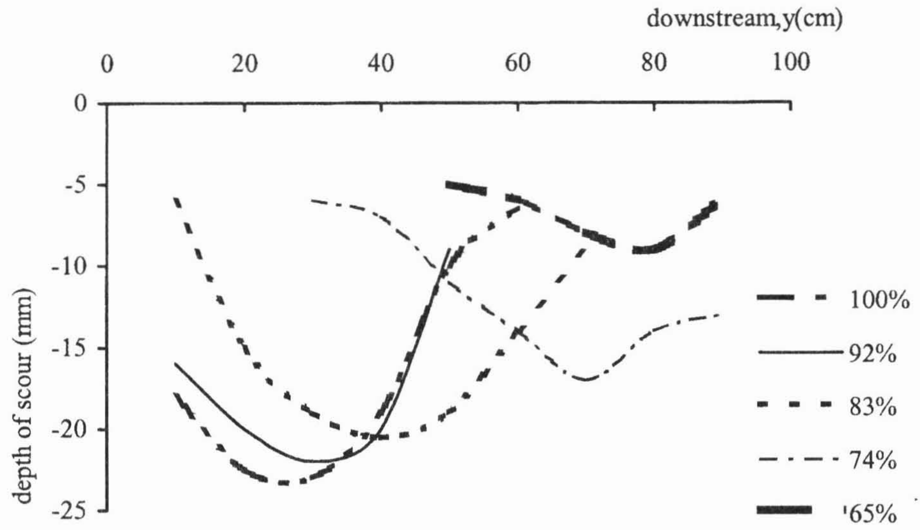

Figure 6: Profile of scoured holes

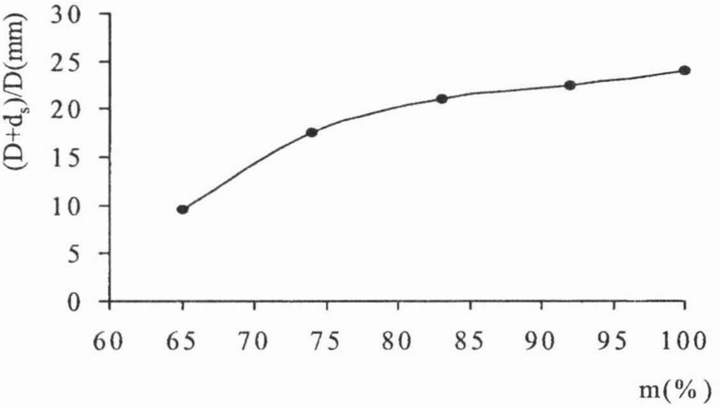

Figure 7: Relation ship for max scoured depth (D+d_s)/D vs m

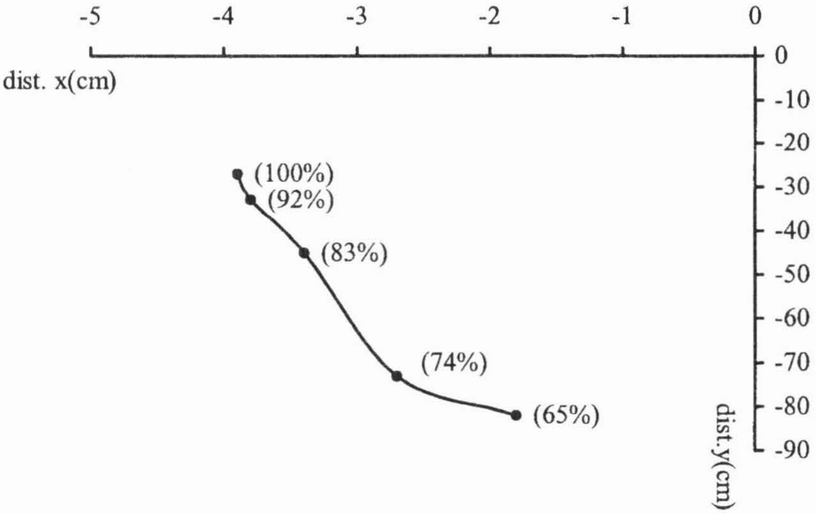

Figure 8: Location of max. scoured depth, ds in relation to % constrictions, (m)

DISCUSSION

The results from all the runs indicate that scouring started to occur when the constriction is greater or equal to 65% and in all cases the velocity in the main channel reached a value of greater than 0.62m/s. It was observed that at this velocity the flow pattern around the constriction started to be funneled through the constricted section hence water could be seen to be more turbulent.

Figure 5 is the profile of scour depth and velocity. It can be seen that the scour attained a maximum depth at a point where the velocity is maximum. The scooped depression shape of the scoured hole is quite deep and smooth illustrating that the capacity of the flow to transport sediment out of the scoured hole is greatest in the region where the water surface started to boil and turbulent in the vicinity must have been affecting the scouring action. The overall profile of scoured holes for all the constrictions (fig. 6) illustrates how the shape and depth of scoured hole changes with distance downstream. The smoothness of the hole is gradually reduced with decreasing m, an indication that lower constriction will offer less transport capacity of the flow regime to scoop and carry the sediment out of scoured hole area. Besides, as m decreases not only the effect of the flow regime channeling is less but it is at some further downstream that the greater turbulence effect is felt, hence scoured hole is very much carried away.

Based upon the dimensional analysis given earlier a plot of $(D + d_s)/D$ versus m in fig.7 clearly indicates a definite correlation between scoured depth and amount of constriction. Maximum depth of scour increases linearly with increasing m beyond the point where m is 74%.

As expected as m is decreased the location of d_s will move not only further downstream but close to the centre of the main channel (fig.8). The reason being as m is decreasing the effect of turbulent is channeled at a much further distance downstream because the passage of attacking current is now much wider. The upper embankment block due to its skewness and in a position which will assist the attacking current help to funnel down the passage of current whereas the lower embankment merely block part of the current. By providing a wider passage as m is decreasing the attacking current on each side is going to be superimposed thus producing greater turbulent at a much greater distance downstream.

CONCLUSION AND RECOMMENDATION

Under the limitations imposed on this investigation the following conclusion can be drawn :-

(i) m ƒ 65% is the limit of scouring for skewed embankment with θ = 70%. It is expected as θ is reduced m will be greater.
(ii) There is a definite linear correlation between $(d + d_s)/D$ and the % constriction m provided m ƒ 74%
(iii) The deepest scoured depth is at the downstream end of embankment block i.e the region of the lower embankment.
(iv) With greater m, the more likely the scour will move upstream towards any offending structures.
(v) With lower m, the more likely the scour will move downstream towards the centre of the main channel.

Obviously more runs are required to confirm the results of further works on this subject would therefore be useful. It is suggested that more variable need to be considered in order to investigate the effects they have on the depth of scouring. For example, it would be interesting to use different grain size distribution to see whether the scour depths are reduced (dramatically?) as σ_g increases. Flow intensity (hence depth of flow) is also an important parameter affecting the scour, therefore the significant of Froude No. could be checked to verify the functional relationship that $(D + d_s)/D = f(u/\ gD)$ derived earlier. Besides the skewness of the embankment (θ) should be varied for a constant m and flow intensity to the variation of scouring depth against θ or for a constant m and θ, variation could be made on flow intensity in order to check the limit of scouring for each constriction. Perhaps a channel with erodible flood plains could be now considered and tested (Sturm T.M).

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