THE BREAKUP OF ARMOR LAYER IN A GRAVEL-BED STREAM WITH NO SEDIMENT SUPPLY

Tao Wang①, Xingnian Liu②

① graduate student, State Key Lab. of Hydraulic & Mountain River Eng., Sichuan Uni., Chengdu 610065, China. e-mail: wtbegin@126.com

② professor, State Key Lab. of Hydraulic & Mountain River Eng., Sichuan Uni., Chengdu 610065, China. e-mail: scucrs@163.com

Abstract Mountain gravel-bed rivers typically display a surface layer that is armored. The armored surface layers form at low flows, but there is little evidence of their condition during floods, when significant hydraulic and ecologic disturbance occurs. Some flume experiments have been used to conclude that armor layers wash out during floods, although other experiments have produced a persistent armor layer. We conducted two runs of flume experiments to study the breakup of armor layers under the condition of no sediment supply. In the two runs of flume experiments, armor layers were formed at low-flow, and then continuously to increase the flow with a small range. Through observing the phenomenon of the experiments and measuring the bed-load transport, we have found that the armor layer would not always be broken up if the flow is higher than the formative flow, unless the flow increases to a certain degree.

Key words breakup; armor layer; gravel bed; bedload transport

1 INTRODUCTION

If the mean bed shear stress is less than the critical stress needed to entrain the largest particles of the bed surface but sufficient to move the finer material, the surface becomes coarser, and consequently, the armor layer begins to develop [Parker and sutherland,1990]. The mountain gravel-bed surface is often coarsened, or armored, relative to the subsurface. Streambed armoring strongly influences channel hydraulics, mediates the exchange of water between flow and bed, and determines the sediment available for transport. The armor layer is stable during typical floods of a lesser magnitude than the formative flow, although it could be broken up by higher flows [Gomez,1983]. In contrast, wilock and detemple (2005) proved the persistence of armor layer even during high flows, but what he emphasized is that the surface grain size changed little.

It is commonly held that the armor layer evident at low-flow “washes out”, becoming finer grained during floods and reforming on waning flows [Parker and Klingeman,1982]. Damia Vericat, ramon J. Batalla and Celso Garcia (2005) describe the breakup and the reestablishment of the bed armor layer in the regulated gravel-bed Ebro river during a flooding period. Sun zhilin have studied the breakup of armour layer through flume experiments, but the flow increased so much higher than the formative flow that the armor layer broke up. Tang zaozao also conducted a flume experiment of the breakup of armor layer, but in the flume experiment the flow increased with a large range, so the armor layer broke up.

It is evident that the armor layer breaks up if the flow is much higher than the formative flow. Well then ,we have not a clear answer about the question “is the armor layer persistent when the flow is higher than the formative flow”. This paper evaluates the persistence of the low-flow armor layer when the flow increases with a little range through several flume experiments.

2 EXPERIMENT REPARATION

2.1 FLUME

The flume experiments were conducted in the state key laboratory of hydraulics and Mountain River engineering [Fig.1]. The slope of the flume could be adjusted between 0 to 2%, and the flume is 16m length, 0.3m width and 0.4m height.

Fig. 1 the experimental flume

2.2 EXPERIMENTAL SEDIMENT

There were two groups of natural river sediment, of which they were group a and group d[Fig2, Fig3]. In order to improve the flow condition in the flume, we just paved the sediment with 10cm thickness and 9.6m length, and the slope of the sediment reach was 5.5‰. In the upstream of the sediment reach, we paved big pebble so as to ensure the pebble not be transported at the experimental flow, and in the downstream of the sediment reach, we jointed a board with the tail end to ensure the tail of the sediment reach not be washed out.

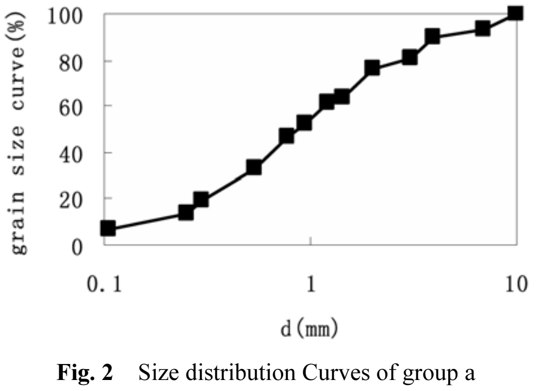

Fig. 2 Size distribution Curves of group a

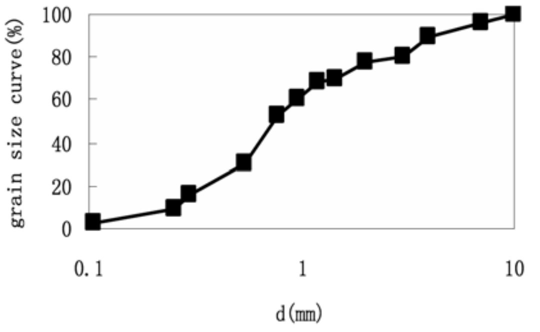

Fig. 3 Size distribution Curves of group b

2.3 EXPERIMENTAL METHOD

The armor layer was formed by covering the sediment of group a on the river bed with low incipient flow. We increased the flow with a small range, and then observed the stability of the armor layer through the experimental phenomenon and the change of bedload transport, and if the armor layer was stable, to continue to increase the flow with a small range till the armor layer was broken up.

The experimental step of sediment group d was the same as the sediment group a.

3 EXPERIMENTAL RESULTS

3.1 THE FLOW CONDITION OF EVERY RUN EXPERIMENT

The two flume experimental flow condition included discharge Q, flow depth h, flow velocity U, slope J_e and bed stress τ_b were listed in Table 1.

3.2 THE BEDLOAD OF EVERY RUN EXPERIMENT

In the experiment, we observed the mobility of the sediment and measured the bedload transport to evaluate the persistence of the armor layer. We did

Table 1 The flow condition of the flume experiment of the breakup of armor layer

Runs		Q(l/s)	H(cm)	U(cm/s)	J_e(‰)	B/h	τ_b(N/m^2)
A0	begin	6.416	4.35	49.16		6.90	
	end	6.416	4.6	46.49	4.573	6.52	2.064
A1		6.696	4.8	46.50	4.581	6.25	2.157
A2		6.984	5	46.56	4.456	6.00	2.185
A3		7.428	5.15	48.08	4.425	5.83	2.236
A4		7.8	5.35	48.60	4.322	5.61	2.268
A5		8.37	5.45	51.19	4.386	5.50	2.345
A6		9.03	5.7	52.81	4.350	5.26	2.432
A7		9.75	5.95	54.62	4.310	5.04	2.516
D0	begin	6.28	4.1	51.06		7.32	
	end	6.28	4.55	46.01	3.863	6.59	1.724
D1		7.2	5	48.00	3.679	6.00	1.805
D2		8.1	5.35	50.47	3.713	5.61	1.949
D3		9	5.75	52.17	3.781	5.22	2.133
D4		9.55	5.85	54.42	3.745	5.13	2.149

not judge that the armor layer was broken up until the sediment mobility was enhanced and the bedlaod transport enlarged suddenly. We could research the bedload transport of the two runs of experiments through Figs.4 and 5.

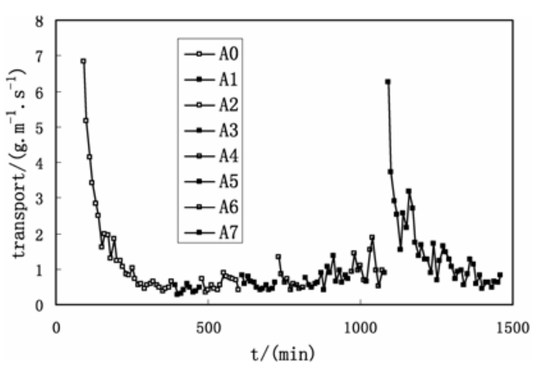

Fig. 4 The process of Bed-load transport rate of run a

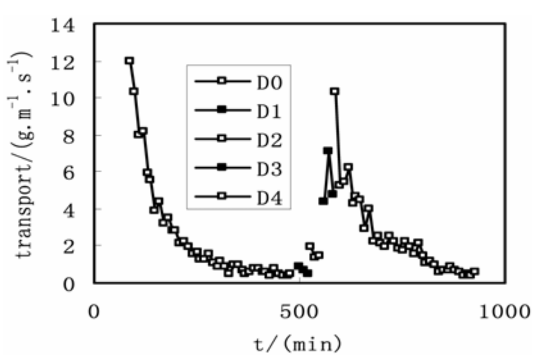

Fig. 5 The process of Bed-load transport rate of run b

3.3 ANALYSIS OF THE EXPERIMENT

From tab.1, we could find that the flow depth and the bed stress have increased with the lightly increased flow discharge. In the incipient armor layer of run a, that is, case A0, the flow discharge was 6.416L/s, the bed stress was 2.064N/m^2; in case A1, the flow discharge was 6.696L/s and the bed stress was 2.157N/m^2; in case A2, the flow discharge was 6.984L/s and the bed stress was 2.185N/m^2; in case A3, the flow discharge was 7.428L/s and the bed stress was 2.236N/m^2; in case A4, the flow discharge was 7.8 L/s and the bed stress is 2.268N/m^2; in case A5, the flow discharge was 8.37L/s and the bed stress was 2.345N/m^2; and in case A6, the flow discharge was 9.03L/s and the bed stress was 2.432N/m^2; in case A7, the flow discharge was 9.75L/s and the bed stress was 2.516N/m^2. And in the incipient armor layer of run b. that is, case D0, the flow discharge was 6.28L/s and the bed stress was 1.724N/m^2; in case D1, the flow discharge was 7.2L/s and the bed stress was 1.805N/m^2; in case D2, the flow discharge was 8.1L/s and the bed stress was 1.949N/m^2; in case D3, the flow discharge was 9L/s and the bed stress was 2.133N/m^2; and case D4, the flow discharge was 9.55L/s and the bed stress was 2.149N/m^2.

From Fig.4, the bedload transport had no obvious increase from the end of case A0 to A5, however, the bed stress increased obviously from the end of case A0 to case A5, moreover, the observation of the process of the experiment have indicated that the bigger sized particle is static. Thus, we could judge that the armor layer was not broken up. In case A6, the bedload transport increased a little comparing with the case A5, but we could find that a few of the bigger sized particle moved. In case A7, the armor layer was broken up because the bedload transport increased obviously, and many bigger sized particles moved.

Analyzed the Fig.5, we found that from the end of case D0 to case D2, the bed stress increased obviously, however, the bedload transport had no obvious increase, so, we judged that the armor layer was persistent. In case D3, the bed stress increased, and the bedload transport increased obviously, moreover, many bigger sized particles moved, so we judged that the armor layer were broken up by the flow. The flow of case D4 was higher than the case D3, the bedload transport was higher than case D3, and the armor layer was broken up seriously.

4 DISCUSSION

We have analyzed the results of the breakup of the armor layer under the condition of no sediment supply in the flume experiments, in which the results was obtained, showing that the armor layer would not always be broken up if the flow is higher than the formative flow, unless the flow increases to a certain degree.

Haschenburger and Wilcock (2003) indicated that complete mobilization of surface grains needs at leastly a flood magnitude of 7-yr return period. Damia Vericat, ramon J. Batalla and Celso Garcia (2005) indicated that the fast breakup and reestablishment of the armor layer observed in the Ebro was an indicator that the river channel is still active 40years after dam’s completion, the channel was relatively unstable, and the armour layer could be completely remobilized during floods of 8-yr return period or more.

Marwan A. Hassan and Michael Church (2000) indicated that between 17% and 47% of the bed stress was estimated to be carried by the structure. We hold the view that the structure of the armor layer bed is different from the unarmored layer bed, and the formative flow enhances the structure of armor layer bed, so that the armor layer could not be broken up until the flow increases to a certain degree.

ACKNOWLEDGEMENTS

This paper is supported by the National Natural Science Foundation of China (Grant No：50579041).

REFERENCES

Damia Vericat, ramon J. Batalla and Celso Garcia, 2006. Breakup and establishment of the armour layer in a large gravel-bed below dams: The lower Ebro. Geomorphology, 76,122-136.

Geomez, B., 1983. temporal variations in bed load transport rates:the effect of progressive bed armouring. Earth surface processes and land forms 8, 41-54.

Haschenburger, J.K., and P.R. wilcock, 2003. Partial transport in a natural gravel-bed channel. Water Resour. Res., 39(1),1020,doi:10.1029/2002WR001532.

Marwan A. Hassan and Michael Church, 2000. experiments on surface structure and partial sediment transport on a gravel bed. Water resources research, 36(7), 1885-1895.

Parker, G., and P.C. Klingeman, 1982. On why gravel bed streams are paved. Water resource. Res., 18,1409-1423

Parker, G., Sutherland, A.J.,1990. Fluvial armour. Journal of Hydraulic Research 28,529-544.

Sun Zhilin, Sun Zhifeng, 200. Transport rate of bed-load in a armoring-process[J]. Journal of Zhejiang University. 27(4), 449-453.

Tang zaozao,1996. Experimental study on the bed-load with a wide distribution[D]. Sichuan united university.

Wilcock, P.R., Detemple, B.T., 2005. persistance of armour layers in gravel-bed streams. Geophysical Research Letters 32, L08402, doi:10.1029/2004GL021772.