THE FORMATION OF RIVER BED CONFIGURATIONS ON MOVABLE BED IN EXPERIMENTAL CHANNEL

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ABSTRACT

This paper describes the results of experimental studies concerning the river bed configurations on movable bed in the open channel flume of the hydraulic laboratory of HOSEI University, Tokyo, JAPAN.

The authors showed evolution process of geneses of sand waves on the base of the results of experiments (`*Engels-Kinoshita's effect'*).

The structure of flow with shallow depth causing to make sand waves is tried to be visible.

1. Introduction


Photo.1 Alternating Bars in TOGAWA, JAPAN [9]

Alternating bars and dunes (bars) are of the typical river bed configuration in the alluvial channel, (Photo 1).

The former is formed on river bed during at the high water in the alluvial channel with the flow of the shallow depth relatively to the width.

It creeps downward slowly. This phenomenon was found by R. Kinoshita in 1950's.

And it is pointed out that these alternating bars are very important to understand the evolution of river bed configuration.

An aerial photo of the water surface of a river stream at the high water shows stripe pattern, that is, several remarkable white lines and rings, (Photo 2).

These white parts are sinking and gathering foams or bubbles and floating trashes which make linear streaks. Among them gray circles and lines are of boiling-up spot. Surface flow velocity at sinking spot is higher than that of boiling spot. And R. Kinoshita verified this fact by Cameron's effect, that is, that the velocity of the moving object or particle is evaluated by means of stereoscopy of 2 photograph sheets of more than 60% overlapped clicked with a small space of time-lag.

The stripe pattern on the photograph is thought to reflect the structure of flow.

River bed configuration consists of several kinds of sand waves. The flow on the river bed affects to make sand waves on the river bed, and sand waves made by the flow affect upon the flow above. Mutual interaction work among them.

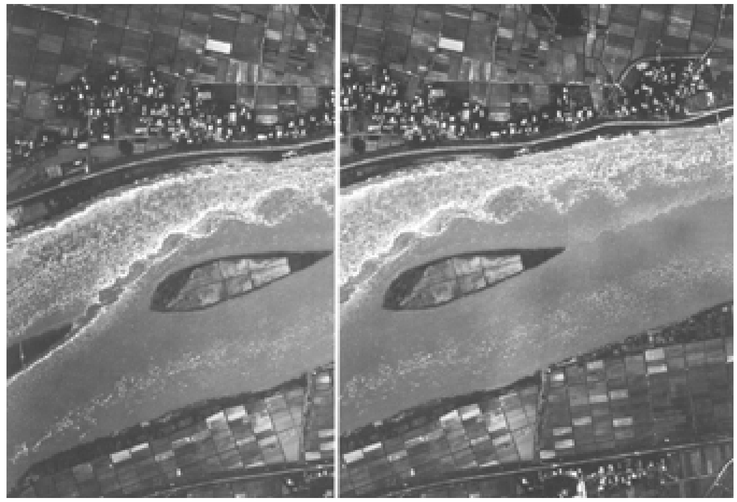

Photo.2 An aerial photograph of the AGANONO River at Flood, 25, Sept., 1966[9]

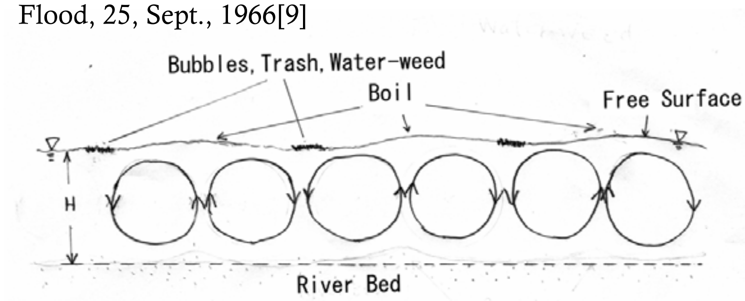

Fig.1 Image of Cellular secondary currents flow [5]

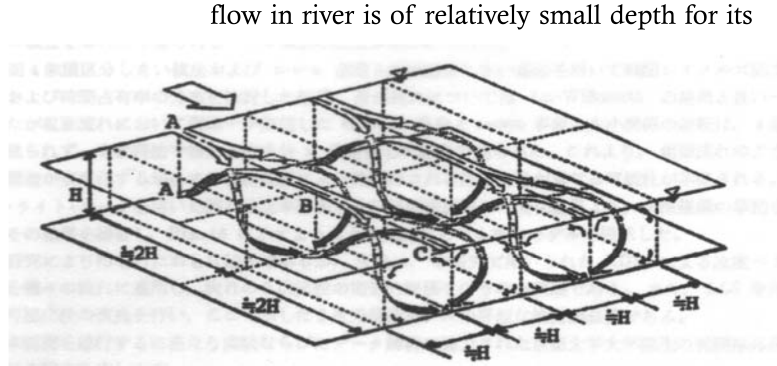

Fig.2 3-dimensional chain-stitch flow model [6]

Generally the cross section of river has small aspect ratio (<1/10 - 1/20 in Japan) so the flow in river is of relatively small depth for its width. In this case R. Kinoshita implied the parallel helicoidal flow model as the flow to bring about parallel sand ridges, a kind of sand waves (Fig.1) and he inferred that the flow might have some same structure even on fixed river bed. And H. Imamoto et al.

proposed another model, the 3-dimensional chain-stitch flow model on the data by LDV (Fig.2).

These two models are not demonstrated directly through distribution of velocity.

2. Hydraulic Experiments on Movable bed in Laboratory

According to hydraulic conditions (Table 1.) with sand of average grain size of 0.072 cm by the experimental channel of 1m width, 40m length at HOSEI University, we can get several kinds of ripples, parallel ripples and alternating bars (Photo.3 - Photo.12). Alternating bars are illustrated in Fig.3. The formation process of these sand waves have some sequence in due order.

Table 1 Experimental hydraulic condition of bed forms

Bed configuration	Discharge Q(l/s)	Water Surface slope I	Mean depth h_m (cm)
Braided flow	0.80 - 6.0	1/50 - 1/222	0.52 - 1.50
Sand ridges	3.8 - 17.8	1/225 - 1/659	0.96 - 1.42
Shewed-lattice ripples	2.9 - 8.1	1/175 - 1/269	1.10 - 2.00
Linguoid ripples	3.9 - 8.8	1/158 - 1/303	1.17 - 2.55
Alternating bars	1.1 - 13.9	1/57 - 1/381	0.77 - 3.45
Alternating bars	3.0 - 20.5	1/51 - 1/333	0.89 - 4.32
Ripples	0.9 - 6.2	1/137 - 1/263	0.70 - 2.62
Ripples II	7.0 - 24.6	1/175 - 1/692	2.62 - 5.20

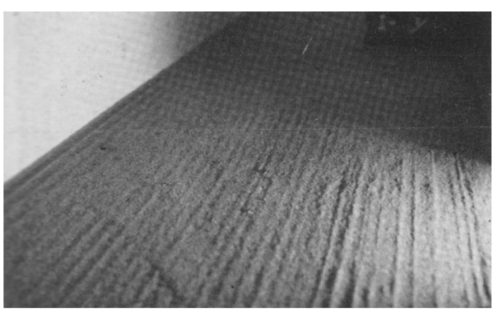

Photo.3 Sand ridges
I=1/435,Q=4.3l/s,hm=1.53

Photo.4 Linguoid ripples
I=1/284,Q=8.4l/s,hm=2.21cm

Photo.5 Alternating barsI+ RipplesII
I=1/133,Q=6.1l/s,hm=1.78cm

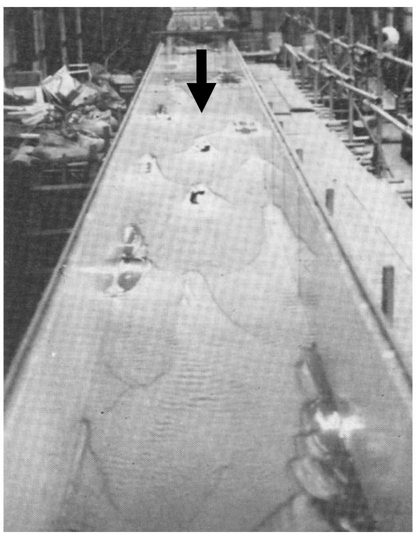

Photo.6 Alternating barsII
I=1/89,Q=5.0l/s,hm=1.58cm

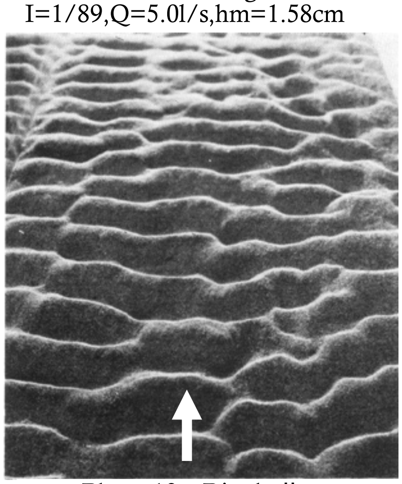

Photo.10 RipplesII
I=1/130,Q=19.9l/s,hm=3.44cm

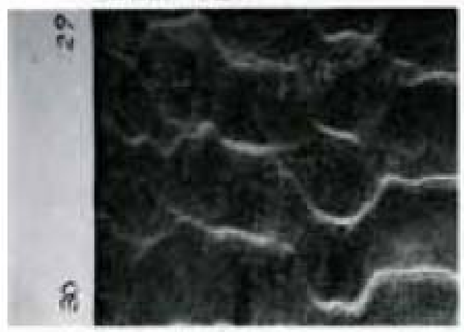

Photo.8 Ripples I

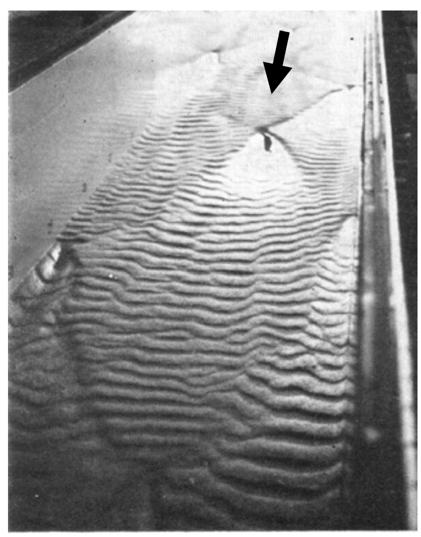

Photo.9 Alternating barsII+RipplesII
I=1/122,Q=11.1l/s,hm=2.55cm

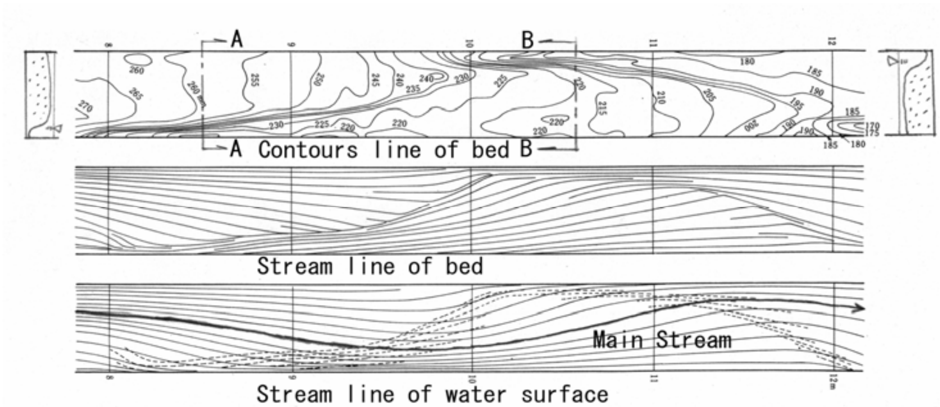

Fig.3 Streamlines of the flow in an experimental flume with well developed alternate bars [9]

The formation process of these sand waves have some sequence in due order.

For example alternating bars reveal themselves via skewed-lattice ripples, linguoid ripples in a short time even through steady flow.

It is thought that skewed-lattice ripples, linguoid ripples and compound alternating bars are of fractal pattern and that the final patterns of sand waves reveal themselves after syntheses of small scales. Engels (1905), Blasius (1910), and Kinoshita (1961) indicated this fact in their papers (Fig.4).

Therefore the authors call the sequential events "*Engels-Kinoshita's effect*".

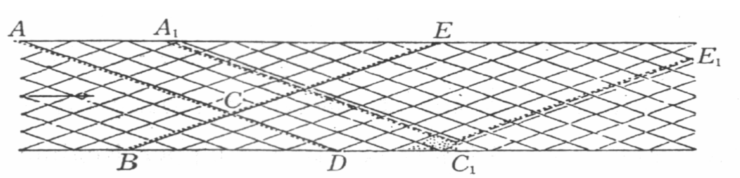

Fig.4-a Explanation of generation of sand waves by Engels [1]

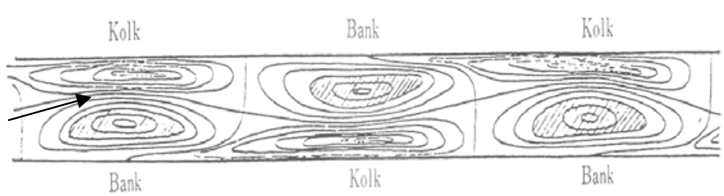

Fig.4-b Alternating bars of Engels [1]

The above processes are summarized in Fig.5.

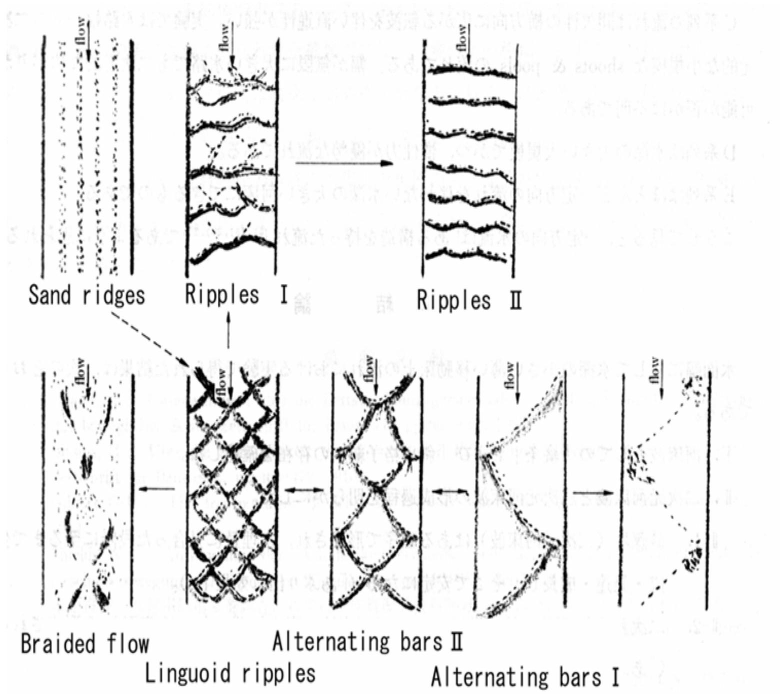

Fig.5 Hierarchical associations of bed forms

3. Velocity Distributions of flow in rectangular channel with fixed bed measured by LDV

Flow and river bed materials are mutually affected and the river bed configuration is made by their actions.

To examine ‘flow structure' velocity-distributions in rectangular channel of small size on fixed bed, 0.4m wide, 10m long with 0.2m water depth, are measured 3-dimensionally by LDV (Laser Doppler Velocimeter) at one thin cross section. The results are shown in Fig.6 and Fig.7. Vector diagrams are presented in Fig.8 and Fig.9.

These figures imply the parallel helicoidal flow model.

These experiments are carried out in only one thin section, so the 3-dimensional chain-stitch flow model can not be check up.

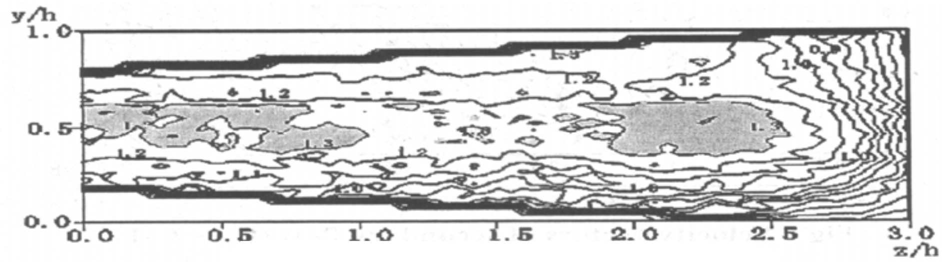

Fig.6 Contours of main velocity U/Um

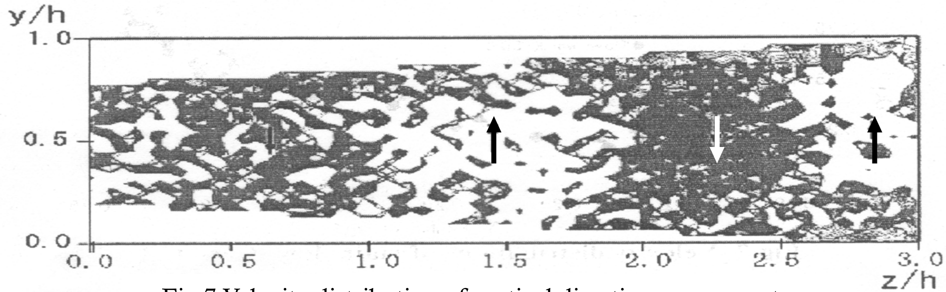

Fig.7 Velocity distribution of vertical direction component

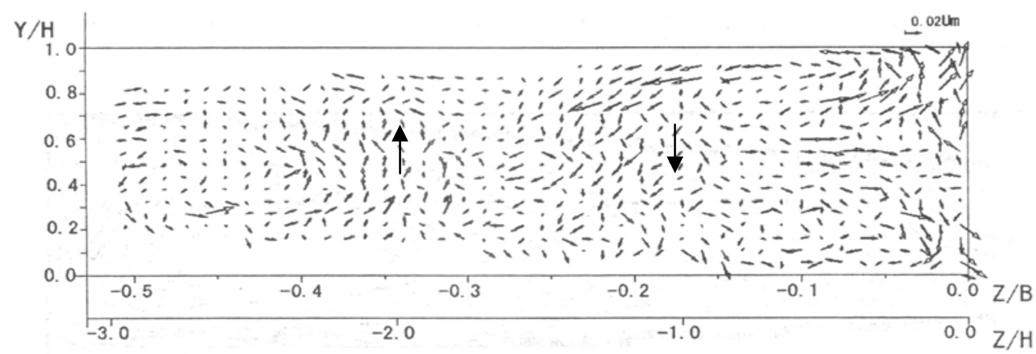

Fig.8 Velocity vectors of secondary flow Case 1

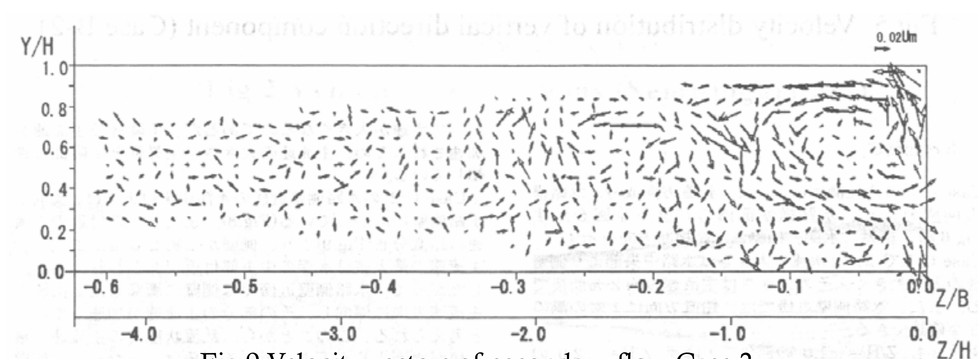

Fig.9 Velocity vectors of secondary flow Case 2

4. Conclusion

1) This paper proves that there are several kinds of sand waves (sand ridges, skewed-lattice ripples, linguoid ripples, parallel ripples and alternating bars) according to the hydraulic conditions, that they have hierarchical association in the formative period, and that evolving their shape one to one, the final type of river bed configuration corresponds to the cohesive hydraulic condition.

This paper explains the process of evolution to the alternating bars from sand waves of small scale.

The results are summarized as follows:

Ⅰ.The formation of alternating bars has a series of stages for developing.
Ⅱ.Three-dimensional ripples formed after a lapse of minutes, in early stage of progress, change to two dimensional ripples.
Ⅲ.Alternating bars always coexist with other sand waves of smaller scale, e.g. ripples and dunes.

The authors would like to propose to call a series of these phenomena the "*Engels-Kinoshita's effect*".

2) Figures of ripples and dunes would be reckoned as irregular, but by the attentive observation they might be comprehended to have the regularity in this paper.

On the other hand, though it has been conceived that alternating bars in the alluvial channel appear during high water, the detailed process of their geneses of elemental sand wave is not yet clear.

A river bed configuration is made by the interactive effect between flow and river bed materials. The authors convince that flow with shallow depth has the some intrinsic structure because sand waves could be created only in shallow stream and that velocity distribution reveals it.

So measurements of velocities in rectangular channel have been carried out by LDA, but not so clear results are obtained.

At present the parallel helicoidal flow model and/or the three-dimensional chain-stitch flow model are most possible flow pattern to cause parallel sand ridges on river bed.

Acknowledgement

The authors thanks to Dr. R. KINOSHITA, professor of JIYUGAKUEN and to the late Dr. S. INOKUTI, professor emeritus of TOKYO University for encouraging us and advising to these investigations and express hurtful thanks to many graduates of HOSEI University who carried out the experiments in long terms.

The authors are also grateful to Dr. Nguyen Van Chanh, the deputy dean of Faculty of Civil Engineering at HO CHI MINH University of Technology and his colleagues, especially to Dr. Nguyen Van Dang in Division of Water Resources Engineering at the same university for the exchange program between HO CHI MINH University of Technology and HOSEI University, and giving chance to present this paper.

References

1) Engels,H.:Untersuchugen uber die Bettausbildung gerader oder schwach gekrummter Flußtrecken mit beweglicher Sohle, Zeitschrift für Bauwesen, pp.663-680, 1905.
2) Blasius, H.: Über die Abhängigkeit der Formender Riffeln und Geschiebbebänke vom Gefälle,Zeitschrift für Bauwesen, pp.465-472, 1910.
3) Gilbert,G.K.:The transportation of débries by running water, U.S.G.S. Professional Paper 86,

1914.
4) Shields, A.: Anwendung der Aehnlichkeitamechanik und der Turbulenzforschung auf die Geschiebebewegung, Erschienen im Eigenverlage der PVWS,Berlin 1936.
5) KINOSHITA Ryosaku: Research of migration of river course in ISHIKARIGAWA (Hokkaido Japan), The Science and Technology Agency, Japan, No.36, pp.77-82, pp.88-92, 1961.
6) IMAMOTO H., ISHIGAKI T.: Velocity Vector Measurement by Laser Doppler Velocimeter in an Open Channel Flow, Bulletin of The Disaster Prevention Research Institute, University of Kyoto.No.28,B-2,pp.477-487,1985.
7) NEZU I.: Open-Channel Flow Turbulence and its Research Prospect in the 21st Century, Journal of Hydraulic Engineering, ASCE, pp.229-245, April, 2005.
8) INOKUTI Syohei: Considerations Hydrauliques Sur La Formation Des Bancs Obliques Dans Le Lit De Cours D'eau Alluvionnaire, Report of the Institute of Industrial Science the University of TOKYO, Vol.14, No.5, Oct., 1965.
9) INOKUTI Syohei: Rivers illustrated (Looking into Rivers), TOKYO University Press, 30 Sept.1979 (In Japanese).
10) HYASHI Taizo, OHASHI M., KOTANI Y.: River Flow Turbulence and Longitudial Vortices, Recent Studies on Turbulence Phenomena(ed. By T.Tatsumi et al.), pp.243-259, 1985.
11) NISHIYA Takanobu., YOSHINO F., MAKINO R.: Étude expérimentale de la Formation des Bancs obliques lors d'une Crue, Bulletin of the College of Engineering, HOSEI University, No.9, pp.29-51, Feb., 1973 (In Japanese).
12) NISHIYA Takanobu.,MAKINO R.: The Classification of Ripples Formed in a Laboratory Flume, Bulletin of the College of Engineering, HOSEI University ,No.22, pp.139-156, 1986 (In Japanese).
13) NISHIYA Takanobu, MAKINO R., IBATA H.: Velocity Distribution of flow with Sand Ridges in Open Channel, JSCE 55th Colloquium, II-226, Sept.2000 (In Japanese).
14) NISHIYA Takanobu, MAKINO R., IBATA H.: LDV Measurement of Velocity Distribution in Open Channel, JSCE Kanto Branch 27th Colloquium, pp.266-267, Mar., 2000 (In Japanese).
15) NISHIYA Takanobu, MAKINO R., IBATA H.: Three Dimensional Measurement of Velocity Distribution in Open Channel Flow with Laser Doppler Velocimeter, Bulletin of Computational Science Research Center, HOSEI University, pp.139-156, Mar., 2000 (In Japanese).
16) NISHIYA Takanobu, MAKINO R., ONO M.: The Measurement of Velocity Distribution in Open Channel Flow by PIV, JSCE 60th Colloquium, II-265, Sept., 2005 (In Japanese).