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Characteristics of Grain Size Distribution in Groin Fields and Their Environmental Implications

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Synopsis

This paper presents the characteristics and environmental implications of the grain size distribution around two typical groin sites in the Kizu River (the Yodo River basin, Japan) and the Fuhe River (the Min River basin, China). The results show that groins enhance sediment sorting processes longitudinally and laterally. Longitudinal sediment coarsening is observed in the mainstream narrowed by groins. The relatively closed bay area between two consecutive groins is capable of trapping fine sediment materials such as silt and clay. Moreover, the area behind a permeable groin exhibits more diversity in terms of grain sizes compared with that behind an impermeable one. Due to lateral sediment sorting, sand ribbons form at the downstream of groins. The results also indicate that the sediment size distributions are closely related to the local channel morphology and the complex flow structure around the groins.

Keywords: groin, sediment heterogeneity, grain size distribution, sand ribbon, field survey

1. Introduction

Alluvial rivers adjust their morphological features and substrate compositions in response to the water and sediment conditions in their drainage basins. Although large variation might exist among different river basins, the physical characteristics such as the stream width, water depth, bed slope, sediment property and channel pattern of a specific river, vary consistently from the upstream origin to the estuary. These characteristics exert significant impacts on the biogeochemistry and stream habitat. As a result, riverine species adapt themselves to accommodate accordingly and an orderly transfer of flora and fauna is commonplace in a river. Consequently, the continuum of the fluvial forms and processes provides the basics of essential concepts advanced in both fluvial geomorphology and aquatic ecology (Pitlick and Wilcock, 2001). Unfortunately, most of the alluvial rivers wandering on our planet have been significantly altered and their continuum has been generally interrupted due to various human interventions over the past several decades. One of the most commonly introduced human interventions is the construction of groins. Groins protrude into the watercourse and make disturbances to the river flow, sediment system and riverine environment. The discontinuity associated with groins has been widely utilized in alluvial rivers for bank protection and navigability improvement (e.g. Zhang, 2005). On the other hand, groins greatly enhance the flow and morphological diversity in their proximities and they have been successfully adopted in practices to restore extinct or damaged aquatic habitats, e.g. Shields et al. (1995), Poizat and Pont (1996), Hartman and Titus

(2010) and Radspinner et al. (2010). In general, the groins work at a relatively local scale, but may have broader-scale implications. Understanding the mechanisms and quantifying the characteristics of the discontinuity caused by groins are important for the effective management of rivers and ecosystems.

The hydraulic and morphological consequences of the interruption due to groins in rivers have been documented by many researchers and engineers, e.g. the early research conducted by Amhad (1953), Garde et al. (1961), Gill (1972), Michiue et al. (1984), Kuhnle et al. (1999, 2002) and others as systematically reviewed by Zhang and Nakagawa (2008), and recent contributions such as Uijttewaal (2005), Biron et al. (2005), Thompson (2006), McCoy et al. (2007), Koken and Constantinescu (2008a, 2008b), Zhang and Nakagawa (2009) and Yossef and de Vriend (2010). According to those studies, it has been well understood that the flow around a groin is quite complex and may be generally separated into several components including the downward flows, bow waves, horse-shoe vortices and wake vortices. The riverbed morphology is characterized by local scouring at the groin toe, sediment deposition in the groin wake and bed degradation in the mainstream. Nevertheless, the discontinuity associated with the substrate composition around groins is still poorly understood despite its crucial significance. It is well-known that the motion of the bed sediment as constitute of the bed itself exerts direct impact on the bed morphology and hence the flow field (e.g. Wu et al., 2000 and Zhang, 2005). On the other hand, the bed sediment is used directly by benthic species, fishes and plants and serves as an indirect indictor for aquatic habitat (e.g. Milhous, 1998 and Shields and Milhous, 1992). In this paper, the characteristics of the grain size distribution in two typical groin fields in Japanese and Chinese rivers are investigated based on field surveys and their environmental implications are addressed as well.

2. Research methodology

This research is mainly based on field surveys along two rivers in Japan and China. The location of the two study sites are sketched in Fig.1 and Fig.2. One is located in the Kizu River (the Yodo River basin) near the Kyoto City, Japan (naming as Kizu site hereafter) and the other is located in the Fuhe River (the Min River basin) near the Chengdu City, China (terming as Fuhe site hereafter). The Min River is one of the largest tributaries of the Yangtze River as shown in Fig.2. The Kizu site consists of two groins to restore a beach landscape for recreation and to enhance riverine bio-diversity nearby. One is impermeable and the other one is permeable. The impermeable one is made of geo-bags and the permeable one is composed of four rows of timbers as shown in Photo1. The mean grain size of the bed materials in this reach is around 5.6mm.The Fuhe site consists of three impermeable groins mainly for the purpose of navigability improvement. For the time being, only the groin bay between the most downstream two groins is selected for investigation as shown in Photo2. The bed in this reach mainly consists of gravels and the mean grain size is about 50mm.

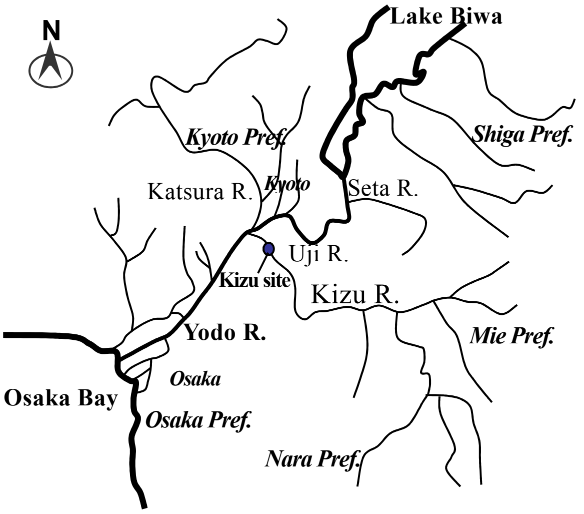

Fig.1 The Yodo River basin and the Kizu site

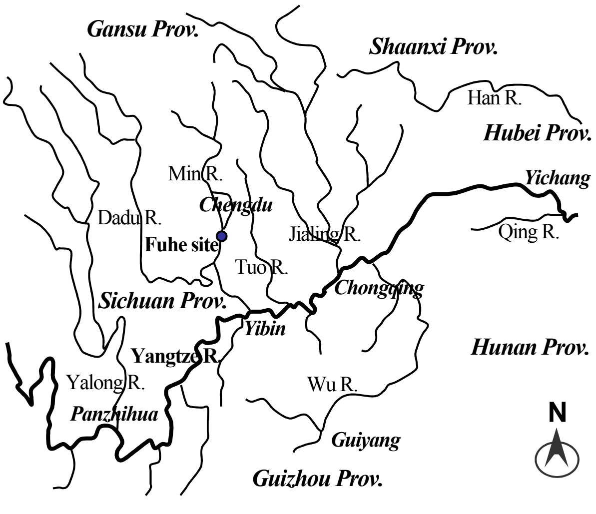

Fig.2 Location of the Min River and the Fuhe site

Photo 1 Groins along the Kizu River (positioning around 34°51’N and 135°44’E)

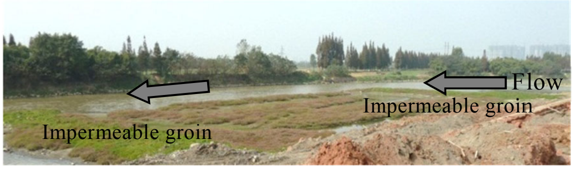

Photo 2 Groins along the Fuhe River (positioning around 30°28’N and 104°03’E)

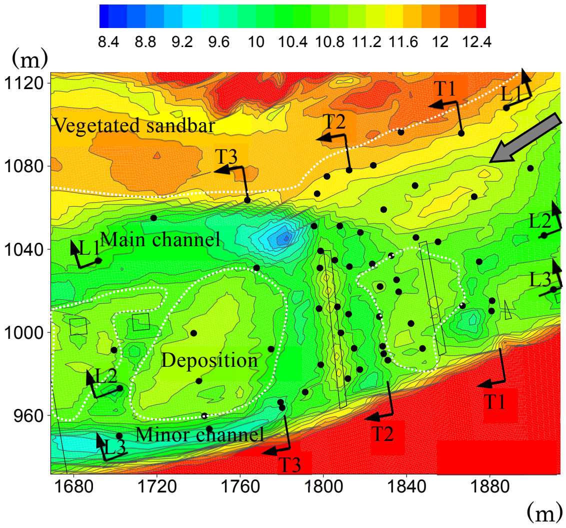

Fig.3 Sediment sampling points superimposed upon the reference bed bathymetries and GPS tracks at the Kizu site

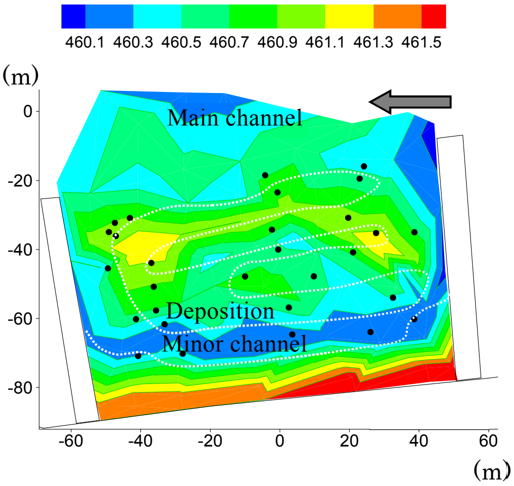

Fig.4 Sediment sampling points superimposed upon the reference bed bathymetries and GPS tracks at the Fuhe site

According to available bed level data, aerial photos and site accessibility, sediment samples at representative points of the two sites (sketched in Fig.3 and Fig.4) are taken from the surfaces of the riverbeds during the winter season of year 2010. Relatively coarse sediment is analyzed with a column of nested stainless sieves and an electronic balance after completely dried out. Fine particles with a maximum size obviously less than 1mm is analyzed with two laser diffraction particle size analyzers: SALD-3000 (Shimadzu co., Ltd., Japan) and Mastersizer 2000 (Malvern Instruments Ltd., UK).

Prior to this study, the authors’ research group has investigated the morphological processes in the proximity of the Kizu site with large-scale experiments and numerical simulations under various flow conditions (e.g. Zhang et al., 2006 and Zhang et al., 2007). It was found that local scour developed at the toe of the impermeable groin at low flow conditions. During high flow conditions, the scour hole had a potential to be filled with sediment transported from the upstream reach and the area along the channel bank might suffer from erosion due to return currents in the groin wake. Furthermore, the flow overtopping the crest of the groin generally led to severe bed degradation along the lee side of the groin body. The erosion at the lee side developed towards downstream and a minor channel would appear. On the other hand, the permeable groin reduced the flow velocity in its wake and generally resulted in bed aggradation downstream of it. Compared with that behind the impermeable groin, the depositional area behind the permeable groin was smaller. Moreover, numerical simulation results suggest that the morphological consequences of the groins were closely related to the complex local flow field and the findings were also applicable to groins in other rivers.

In this study, the grain size distributions are focused on, while the bed bathymetries are not measured in details. The typical topographic features, in particular the extents of the depositional area, are recorded with the aid of a mobile GPS (Global positioning system) unit GPSmap 60CSx (Garmin Cooperation). The sketches of the depositional area are depicted in Fig.3 and Fig.4 (dotted lines), together with available historic bed level data of the Kizu site (year 2006, 5m resolution) and the Fuhe site (year 2000, scattered points) for reference. It is found that the sketched depositional area in the Kizu site agrees well with that plotted from the 2006 bed bathymetrical data. In fact, similarities in other topographic features are also recognized during the field investigation and photography. These suggest that the year 2006 bed bathymetry could express the riverbed topographic features in year 2010 with a reasonable accuracy. Hence, the bed level information of year 2006 is used directly in the analyses of the Kizu site if necessary. In the Fuhe site, the bed geometry is much sophisticated in the groin bay, indicating the complex flow conditions there. There are some similarities between the GPS tracks and the year 2000 bed contours such as the locations of the depositional area and the minor channel. However, discrepancies are also evident, e.g. the incisions of several small channels into the depositional area are distinguishable in both years but the locations of those channels are a bit different. These findings demonstrate that the basic morphological properties around the groins have almost maintained although there have been changes in the bed level details over the past decade. Keeping this in mind, we are not too particular about the details of the bed elevations for the analyses of the Fuhe site in the following contexts. Instead, the inherent properties associated with the bed morphologies are extracted and emphasized if necessary.

3. Results

During the field investigations, it has been found that the reaches equipped with groins exhibit obvious diversity in bed sediment properties compared with other reaches of the channels. The sediment particles vary in space not only in the longitudinal direction but also in the lateral direction. Moreover, the sediment properties in the bay area between two consecutive groins are evidently distinguishable from those in the mainstream even with the naked eye. In this section, one of the most important parameters for the quantification of the substrate composition and habitat heterogeneity, i.e. the grain size distribution, is selected for analyses.

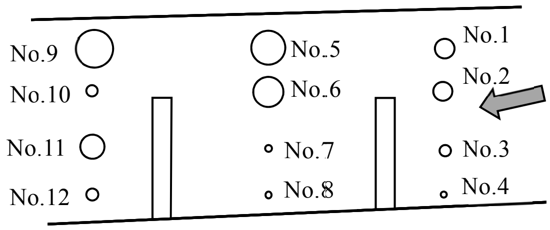

Fig.5 Sketch of representative sampling points

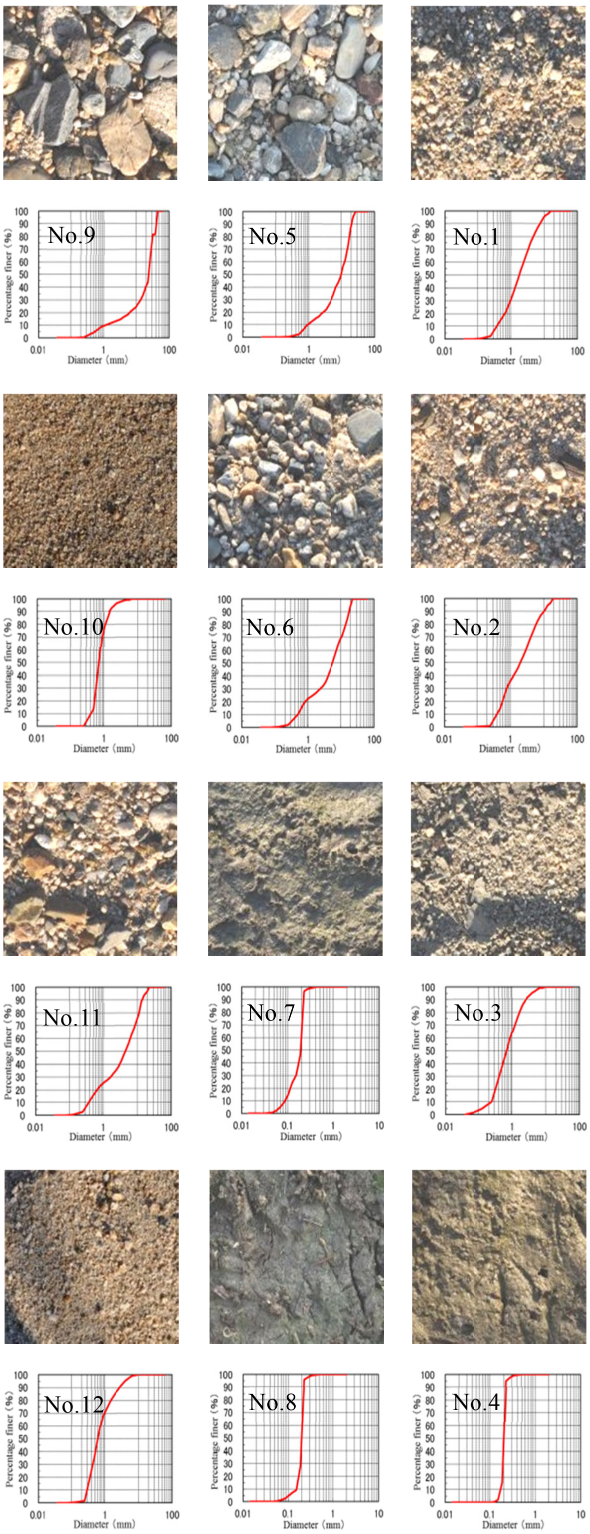

Fig.6 Samples at representative sampling points

3.1 A general image of grain sizes around groins

In order to obtain a general idea on the grain size distribution around groins, the photos and the sediment sieve analysis curves of samples at several representative points taken at the Kizu site are presented first. The sketch of the groins as well as the locations of the points is depicted in Fig.5. For clarity, the size of the circle in the figure gives qualitative information on the mean grain size at each point, while the details on the grain size distribution are shown in Fig.6.

The photos provide visible evidences on the sediment heterogeneity in the proximity of the groins. The sediment covers a broad range of grain sizes, including silt, sand and gravel obviously. The distribution of the grain sizes does not follow the rule of thumb any more that alluvial rivers exhibit gradual fining of bed materials in the down-valley direction. The continuum of the river in terms of substrate composition is clearly interrupted by the groins. Moreover, different from the effect of the interruptions caused by dams or weirs which is generally simplified as upstream fine sediment deposition and downstream bed coarsening, the discontinuity due to groins is much more complex. The mean grain sizes and their distributions show dramatic variations in a very confined local area in the proximity of the groins.

3.2 Longitudinal distribution of grain sizes

The mean grain sizes D and the geometric standard deviations σ_g of the samples at typical longitudinal cross-sections in the Kizu site are depicted in Fig.7 and Fig.8. For clarity, the bed level, the projected area of the groin bay and the mean sediment size within the reach are plotted in the figures as well. The locations of the cross-sections are sketched in Fig.3. Amongst them, Section-L1 lies in the mainstream, Section-L2 is across the groin bay and Section-L3 is near the bank and across the groin bay.

Due to the existence of a large vegetated sandbar as sketched in Fig.3, the bed topography around the groins is a bit complex. However, the typical longitudinal morphological features are still well distinguishable in the three sections as shown in Fig.7. The bed profile in the mainstream is relatively simple, highlighted by severe local scouring. In the groin field, the bed levels vary a lot in the longitudinal direction. The immediately upstream of the permeable groin is eroded and the sediment deposits in the groin bay. Both the upstream and the downstream of the impermeable groin suffered from erosion and deposition takes place in the wake zone.

As is known, bed materials in alluvial rivers generally turn finer and finer if one goes down and down the river. However, it is noted in all longitudinal sections of Fig.7 that the sediment is fine in the upstream of the groin bay and is coarse in the downstream of it. In the upstream area, the mean sizes of all sediment samples are less than the mean sediment size within the reach. In other areas, differences are recognized between the section in the mainstream and sections in the groin bay. The groin bay (Section-L2 and Section-L3) is found to be covered with very fine sediment particles, while the part of the mainstream just in front of the groin bay (Section-L1) shows obvious bed sediment coarsening indicating a possible existence of an armor layer. The findings here are not surprising considering the flow velocity reduction in the groin field and the flow velocity acceleration in the mainstream caused by groins as have been well documented by previous researchers such as Koken and Constantinescu (2008b), Zhang and Nakagawa (2008), Zhang et al. (2009) and Yossef and de Vriend (2010).

As to the value of σ_g, it is found that sediment samples having a mean size less than 0.5mm are generally characterized by a relatively small σ_g and hence are relatively uniform according to Fig.7 and Fig.8. It implies that the relatively coarse sediment is possibly more non-uniform since there are more voids in the mixture allowing various finer particles to fill in. The value of σ_g in the mainstream (Section-L1) seems not show any obvious relation with the location or the mean size of the sediment samples. But in the groin field, there are some interesting findings. Section-L2 and Section-L3 suggest that the most uniform sediment locates in the groin bay, followed by the upstream of the groin bay and the downstream area of the groin bay. It indicates that the existence of the groin bay plays an important role in the longitudinal sediment sorting process.

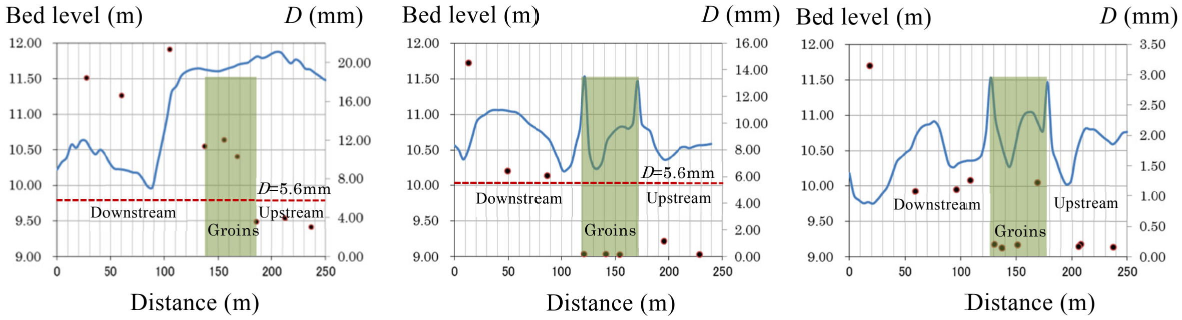

Fig.7 Bed level (lines) and mean grain sizes (points) along longitudinal sections L1, L2 and L3 (Left: Section-L1; Middle: Section L2; Right: Section L3)

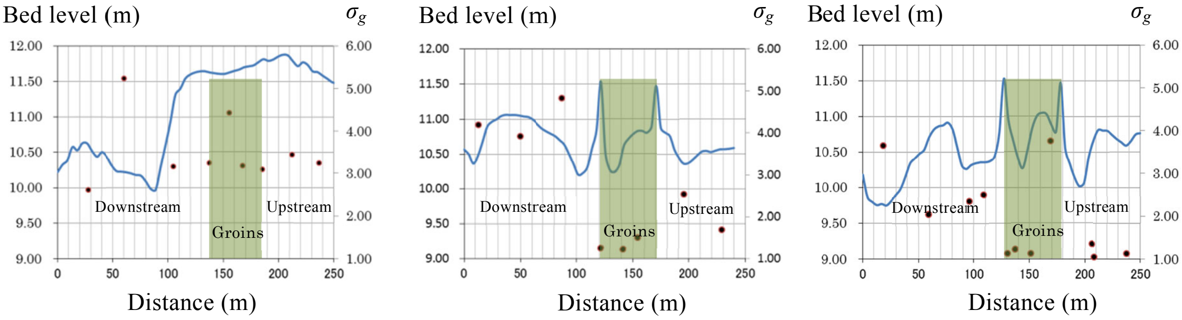

Fig.8 Bed level (lines) and geometric standard deviation of sediment (points) along longitudinal sections L1, L2 and L3 (Left: Section-L1; Middle: Section L2; Right: Section L3)

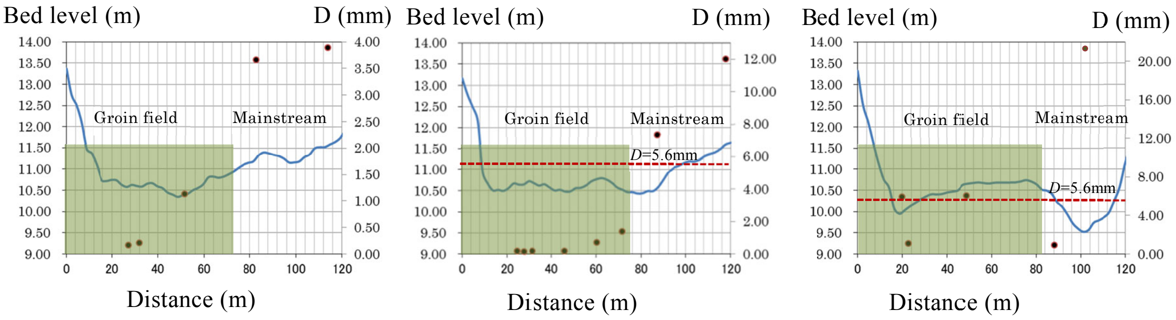

Fig.9 Bed level (lines) and mean grain sizes (points) along transverse sections T1, T2 and T3 (Left: Section-T1; Middle: Section-T2; Right: Section-T3)

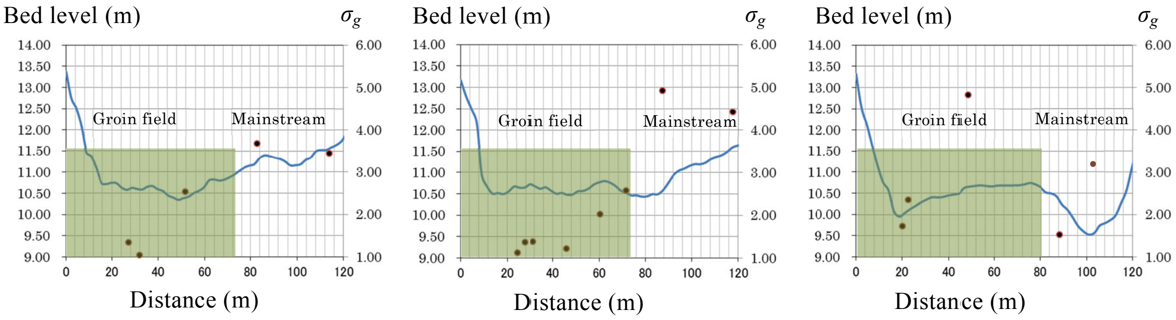

Fig.10 Bed level (lines) and geometric standard deviation of sediment (points) along transverse sections T1, T2 and T3 (Left: Section-T1; Middle: Section-T2; Right: Section-T3)

3.3 Lateral distribution of grain sizes

In Fig.9 and Fig.10, the mean diameter and the geometric standard deviation of sediment samples taken from the Kizu site are plotted along several transverse cross-sections, together with the bed level, the projected area of the groins and the mean sediment size within the reach. The locations of the cross-sections are sketched in Fig.3. In details, Section-T1 situates in the upstream of the groin bay, Section-T2 is across the groin bay and Section-T3 locates at the downstream of the groin bay.

It is noted in Fig.9 that the bed level in the groin field is lower than that in the mainstream along Section-T1, coinciding with the fact that the bed is eroded immediately upstream of the permeable groin. In Section-T2, bed degradation in the mainstream and the complex bed topography in the groin bay are evidently visible. The bed level in Section-T3 gives a clear image on the main channel, the minor channel and the deposition area between them.

The changing trend of either D or σ_g along Section-L1 and Section-L2 is rather similar according to Fig.9 and Fig.10. From the left bank of the channel towards the mainstream, the sediment gradually increases in size and the σ_g also shows general increase within the groin field except several points. In the mainstream area, both D and σ_g are much larger than those in the groin field. The sediment mean sizes in the mainstream of Section-T2 are particularly large, around twice of the mean sediment size of the reach. It is understandable as the width of this area is dramatically narrowed by the groin bay and significant flow acceleration takes place there.

In the downstream of the groin bay, i.e. Section-L3, the situations are completely different. The alternated distribution of coarse and fine sediment is observed along this section, indicating the existence of sand ribbons. Sand ribbons here refer to the overlay of longitudinal fine sediment strips on the coarse sediment texture and there are confirmed with naked eye during the field investigation. The locations of the fine sediment points indicate that the sand ribbons are situated on the slopes of the main channel and the minor channel. The mean sediment sizes of the two sand ribbons are very similar but the values of σ_g are a bit different. The sediment in the sand ribbon near the main channel is found to be more uniform than that near the minor channel. In fact, the sand ribbon near the main channel is also much thicker and wider than that near the minor channel according to the field investigation. These differences are caused by the differences in the bed topography (see Fig.10) and the secondary flow between the main channel and the minor channel. Previous studies such as Colombini (1993) suggest that the formation of sand ribbons is closely related to secondary flows. Although the secondary flows have a lot of origins such as those due to the inhomogeneity of turbulence, the gradient in channel geometry and the difference in bottom roughness, the change of the bed topography due to the existence of groins is considered to play the most important role.

3.4 Grain size distribution in the groin bay

Both longitudinal and lateral grain size distributions indicate that the sediment particles in the groin bay are finer and more uniform compared with those outside of the bay. Due to the complexity of the bed topography in the groin bay, the distribution patterns of sediment particles are also complex. Therefore, it is necessary to draw a clearer image by focusing on the groin bay area. In Fig.11 and Fig.12, The grain size distributions in both the Kizu site and the Fuhe site are plotted, together with the bed level information. It has to be mentioned that the upstream groin in the Kizu site is a permeable groin but that in the Fuhe site is an impermeable one. The permeable groin allows water and sediment passing through, while the impermeable one blocks the flow and sediment until it is submerged.

The sediment samples in the groin bay of the Kizu site cover a much wider range of sediment sizes compared with those of the Fuhe site although the bay area of the former one is rather smaller than that of the latter one. Moreover, most of the sediment in the Fuhe site falls in the range of silt and clay and the size of which is much finer than that of the Kizu site. There are two probable reasons. One is the approach flow condition, in particular the flow direction. Due to the existence of the sandbar, the approach flow direction in the

Kizu site varies according to upstream flow discharges, which may exert certain impacts on the direction of sediment transport and sediment size distributions in the groin bay. But the second one, i.e. the upstream groin condition is mainly responsible for the differences. The groin bay closed with an upstream permeable groin exhibits more diversity in terms of sediment sizes, and hence possibly more diversity from the viewpoint of the environmental system. It is interesting to mention that the Kizu site is colonized by several plant species, while the Fuhe site is dominated by a single species during the field investigations.

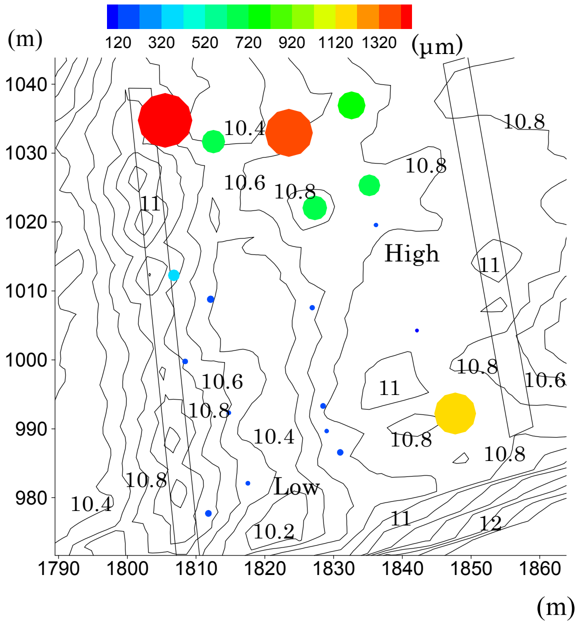

Fig.11 Mean grain size distribution in the groin bay of the Kizu site

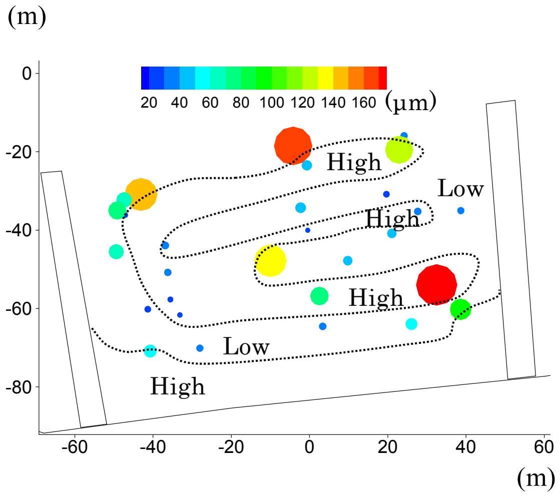

Fig.12 Mean grain size distribution in the groin bay of the Fuhe site

Despite the significant differences in the magnitudes of sediment mean sizes, there are some common features between the two sites. In the area close to the mainstream, sediment sizes are generally larger compared with those in the area far from the mainstream. It is due to the great differences in the flow velocity. The sediment sizes also show some relation with the bed topography. If one characterizes the bed morphological features in the two groin bays, the beds are simplified as follows. In the Kizu site, the bottom left corner may be considered as a low land area and the other area is relatively high land with scattered pools. In the Fuhe site, a large depositional area occupies most of the groin bay. The depositional area is surrounded by low land area and is like an island. The island is in an ε-shape and has a potential to be separated into three parts. In both sites, the sediment samples taken at a high elevation are generally lager in sizes than those taken at a low elevation although there are several exceptional points. It indicates that the low land area in the groin bay serves as sink tank for fine sediment.

4. Discussions

4.1 Flow structure

From the field survey results, it comes that the grain size distributions show strong relations with the local bed morphology. However, different from laboratory experiments under controlled flow and sediment conditions, an explicit relationship between the grain size distribution and the bed morphology is not readily derivable with limited information. Besides the possible uncertainties in the field survey data, the complexity of the bed surface itself is also a great concern. As is known, the surface of the alluvial riverbed is generally active and experiences various flow discharges and corresponding topographic changes. Each factor or event has a possibility to leave its footprint more or less upon the bed and these footprints are not easily isolated. However, these arguments do not mean that the grain sizes are distributed randomly. On the contrary, the results presented in the previous contexts draw clear images of the typical patterns of grain size distributions in the proximity of groins in actual rivers, corresponding to the typical bed morphologies. It suggests that there should be some underlying processes and certain rules which the sediment particles follow during their movement.

In order to further the understanding of the grain size distribution patterns, the flow structures corresponding to the bed morphologies in the proximity of the Kizu site are investigated with numerical methods. The flow directly exerts forces on sediment particles and is the most important engine for sediment movement. The representative flow fields are simulated with a 2D numerical model developed by the first author (Zhang et al., 2006) under two kinds of discharge scenarios: 500m^3/s and 2000m^3/s. The model is formulated on unstructured mesh and allows the exact resolving of the groin details and the irregular river boundaries. The discharge of 500m^3/s corresponds to the condition that the vegetated sandbar just becomes submerged. Under this flow discharge, the impact of groins is dominant. The discharge of 2000m^3/s is equivalent to the bankfull discharge of the river and the effects of meso-scale and large scale bed deformations such as the migration of sandbars are not negligible any more. The simulated velocity vectors and their magnitudes are plotted in Fig.13 and Fig.14. Fig.13 shows evidently that the flow direction is significantly controlled by the groins. In the upstream reach of the groins, the flow is in a direction intending to attack the left side of the channel. But when it approaches the upstream permeable groin, the flow becomes almost parallel to the bank of the channel. After passing the downstream impermeable groin, part of the flow is diverted towards the mainstream. As is known, the direct benefit is that the bank is prevented from erosion. In Fig.14, however, the controlling of the flow direction by groins is not evident. Since the flow depth is relatively large, the groins function as roughness elements. As to the magnitudes of the velocity, the absolute values are not paid too much attention. It is observed that alternated distributions of high and low velocity zones in the longitudinal direction and significant flow acceleration in the mainstream area near the groin bay are evident in either case. The flow structure gives some hints on the sediment sorting processes around the groins and is able to partially explain some of the typical distribution patterns observed in the field.

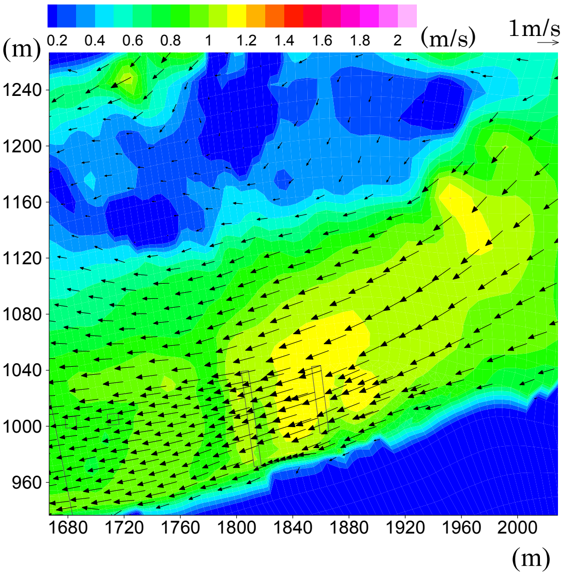

Fig.13 Simulated 2D flow vectors and isovels in the proximity of the Kizu site (500m^3/s)

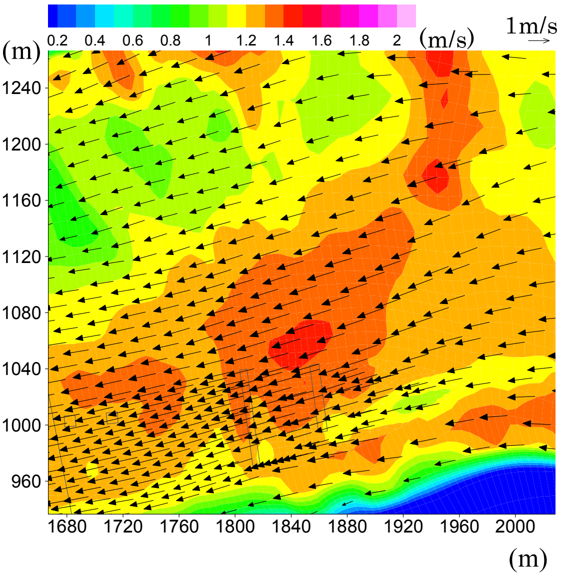

Fig.14 Simulated 2D flow vectors and isovels in the proximity of the Kizu site (2000m^3/s)

4.2 Environmental implications

The results discussed above clearly demonstrate the discontinuity of substrate compositions caused by groins. Since direct measurements of the aquatic species are not made in this study for the time being, a quantitative assessment of the quality of the habitat created by the groins is not readily available. However, the environmental implications of the grain size distributions are discussable with the aid of the reference information from previous research conducted by morphologists and ecologists.

It is well-known that simple relations between substrate grain size distributions and biological variables may be misleading but the grain sizes do exhibit close linkage with the distribution and heterogeneity of aquatic species. The periphyton, as an important indicator of water quality and food sources for benthic organisms, relies strongly on the properties of the substrate, e.g. Yamada and Nakamura (2002) provide evidences from field surveys that the increasing of fine sediment results in decreasing of chlorophyll a and increasing of non-living periphyton. The bed sediment materials are inhabited by benthic organisms that provide food for fish. Hence, the substrate grain size plays the most important role in the community composition and density of benthic species. Field studies on the distribution of macroinvertebrates indicate that highest diversity is generally found in communities composed of attachment types in relatively coarse sediment beds, while cohesive soft sediments are often densely populated by less diverse assemblages of burrowing types (Shields and Milhous, 1992). The mobility of fishes, especially adult fishes, complicates the linkages between sediment properties and fish populations. However, fishes use sediment directly for cover, feeding and spawning, indicating the importance of substrate sediment in their life cycles. There is abundant research work related to various fishes and substrate properties, e.g. Wood and Armitage, 1999, Osmundson et al., 2002 and Sternecker and Geist, 2010.

In general, there is a consensus that a cobble or a gravel bed exhibits more bio-diversity compared with a sand or a fine material one and there is a well-established review paper given by Shields and Milhous (1992). Moreover, the deposition of fine sediment usually has negative biological effects in the lotic environment and a recent review article is available from Kemp et al. (2011). As the groins result in riverine areas with a mosaic of substrate types in their proximities, a diverse distribution of biological species around them is expectable. On the other hand, it is also noted that the possible appearance of immigration species is foreseeable since new substrate types are created by the groins. As different substrate types distribute in a very small reach around the groins, the tropic levels of the pristine local species might be changed and the positions of the immigration species on the food chain may exert impacts on bio-richness and bio-diversity. From the viewpoint of habitat quality, the groin bay enclosed by permeable groins is preferred because generally less fine sediment will accumulate in the bay area compared with that enclosed by impermeable ones. A comprehensive understanding on the habitat quality should be made by including also other information such flow fields and bed configurations.

5. Conclusions

In this study, spatial distribution characteristics of grain sizes on the bed surfaces around typical groins in the Kizu River (the Yodo River basin, Japan) and the Fuhe River (the Min River basin, China) are investigated. Based on the research results, the impact of groins on grain size distributions in alluvial rivers and its environmental implications are clarified.

The results indicate that the grain size distribution exhibits some typical features and shows close relations with the local bed morphology and the velocity field. The groins enhance sediment sorting processes in their neighborhood both longitudinally and laterally. In the mainstream area, dramatic sediment coarsening is found in front of and downstream of the groin bay. In the groin field, coarsest sediment appears in the downstream of the groin bay, followed by the upstream of the groin bay and the finest sediment accumulates in the groin bay. The grain size distribution patterns in the groin bay is rather complex. In general, the sediment at a low elevation is finer than that at a high elevation within the groin bay. The permeability of the upstream groin of the groin bay also exerts impact on the grain size distributions. The groin bay behind a permeable groin is more diverse in terms of grain sizes. The formation of sand ribbons in the downstream of groins deserves special attention, which corresponds to the secondary flows triggered mainly by changes in the local bed morphology around groins.

The information presented in the paper provides first-hand evidences on the grain size distributions around groins in alluvial rivers. It has to be mentioned that the results are consistent with those obtained from fundamental laboratory experiments and numerical simulations associated with a single impermeable groin under idealized flow conditions (Zhang et al., 2010). The conclusions drawn from the study is of reference for scientific management and possible improvement of the river groins in both sites. Moreover, it is also of reference for a better understanding on the mechanism and consequences of heterogeneous sediment transport in local scales. Nevertheless, further field surveys on the temporal changes and comparisons with experiments as well as simulations are also necessary, and which are crucial concerns in the future study.

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水制域における河床材料の粒度分布特性とそれらの環境関連性に関する研究

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要　旨

本稿は，木津川（淀川流域）及び中国府河（岷江流域）にある水制群を対象に，水制周辺の地形及び河床材料の現地調査結果の基にした，河床表層材料の粒度分布特性とそれらの環境関連性に関する研究報告である。今回の調査により，水制周辺における流砂の縦断及び横断方向における分級現象の重要性を指摘した。水制により河床材料の連続性は失われ，河川主流部の河床では粗粒化現象が見られ，水制と水制の間ではシルトや粘土などの細かい砂が堆積しやすい区間になる。さらに，透過型水制の背後では不透過型のそれよりも河床材料の粒度分布の粒径範囲が広く，環境にも優しいと考えられる。水制直下流では二次流などの影響で顕在化する粗粒化領域，そしてその周囲に細粒化する領域（サンドリボン）の存在も確認した。また水制周りの地形及び流れに関する情報に配慮したところ，粒度分布は河床形態と局所的流れ構造と密接な関連性があることも判明された。

キーワード：水制，流砂の非均一性，粒度分布，サンドリボン，現地計測