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PRIMARY TREATMENT OF DREDGING SYSTEM FOR DAM SEDIMENT REPLENISHING TO THE RIVER *

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* *Traitement primaire du système de dragage pour les sédiments de barrage rejetés dans la rivière*

1. INTRODUCTION

Sediment replenishment that is to supply dredged sediment artificially to the downstream river is one of attractive solutions to solve reservoir sedimentation problem and to maintain sediment continuity for downstream river from the environmental point of view. In case of the sediment replenishment, it is important to estimate and mitigate water quality changes if the reservoir sediments contain very fine materials which may cause turbidity problems or nutrient discharge[1)-3)].

The purposes of our study are how to dredge sediment from reservoirs safely, and how to produce the appropriate grain sized material from the sediment which contains very fine sediment nutrients.

In this paper, we present the application of a system utilizing an ejector pump to suck up sediment and two spiral classifiers to produce the appropriate grain sized materials from the sediment. To confirm the effectiveness of the developed treatment system, field tests were executed near a check dam of the Nunome dam reservoir in Yodo river system[4)]. The result shows that our proposed method is effective to achieve the purpose of our study.

2. FEATURE OF MACHINE USED

Ejector pump

By spouting the high-pressurized jet water from the nozzle, the ejector pump (Figs. 1, 2) is able to produce the energy required to transport the dredged sediment slurry[4)]. The ejector pump is structurally simple and easy to maintain since it has no rotary parts such as an impeller wheel. This pump has two special characteristics: one is a controlled air inlet into the pump; the other is the inner straight pipe which is not throttled. These are very effective for the cavitation control and abrasion resistance of the pump. By changing the water pressure and the nozzle diameter, it is easy to adjust the potential head and the suction rate. Another advantage is that sediment can be washed out by water turbulence with air while passing through the pump.

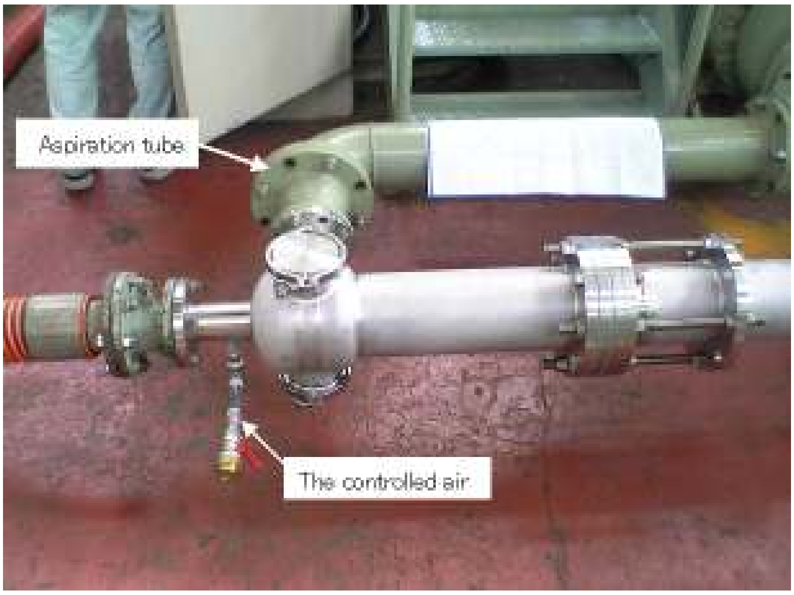

Fig. 1
Ejector pump
Pompe à éjecteur

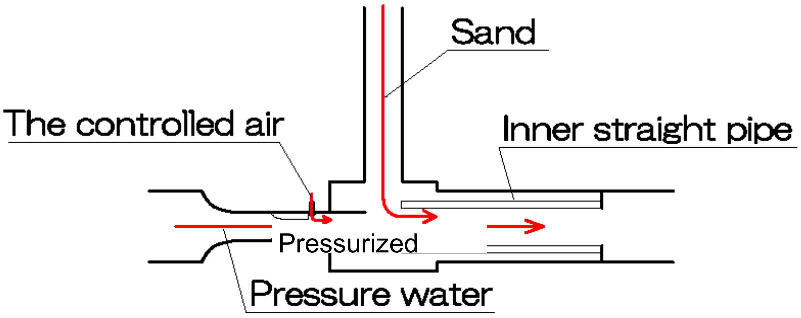

Fig. 2
Schematic chart of ejector pump
Schéma de pompe à éjecteur

SPIRAL CLASSIFIERS

The spiral classifiers named Escargot (Fig. 3) are compact devices that separate sand from slurry[5)]. These cylindrical containers compose spiral watercourse shown in Fig. 4. Diagonal plates with slits (Fig. 5) are installed in the device to settle sand particles on. The settled sand falls through the slits to the bottom of the container. The lower part of the container is cone-shaped to collect sand effectively, and the sand is discharged by a screw conveyor attached to the container. For the field test described later, the system consists of two spiral classifiers connected, the first one (Small Escargot) collects relatively coarse sand, and the second one (Big Escargot) is lengthened watercourse to collect relatively fine sand. The grain size distribution of the classified sand will be able to be controlled by designing the length of the watercourse properly.

Fig. 3
Spiral classifiers (Escargot)
Classificateur à spirale (escargot)

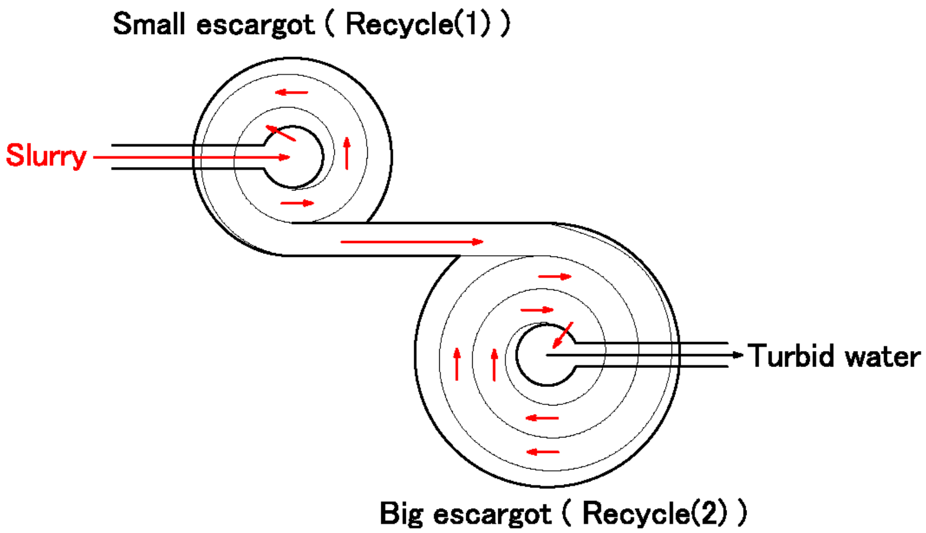

Fig. 4
Schematic plane of streamlines in spiral classifiers
Schéma de circulation de l'eau dans les classificateurs à spirale

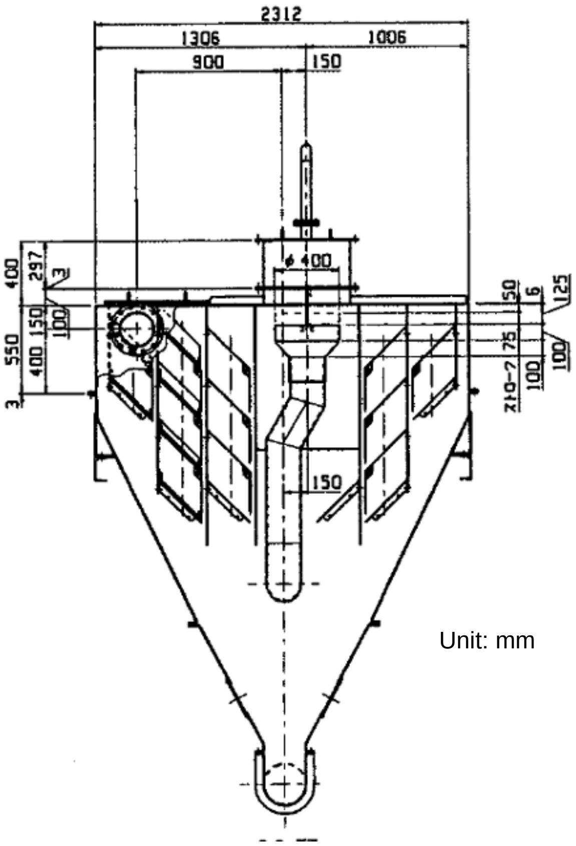

Fig. 5
Cross section of spiral classifier (Escargot)
Vue en coupe d'un classificateur à spirale (Escargot)

3. OUTLINE OF THE FIELD TEST AT THE NUNOME DAM

LACE OF THE FIELD TEST

Field test was executed to confirm the effectiveness of the treatment system for reservoir sediment near the check dam in the Nunome dam reservoir[6)]. Outline of the Nunome dam is shown in Table1.

The check dam located upstream of the Nunome dam as shown in Fig. 6 was constructed both for reservoir sedimentation and water quality management. In the shallow sub-reservoir upstream of the check dam, inflow sediment containing fine materials and nutrients can be settled and deposited. If these deposited sediments will be removed timely, the check dam will highly contribute to reduce sediment and nutrient loads to the main-reservoir.

Table 1
Outline of the Nunome dam
Périmètre du barrage de Nunome

River	Dam height / length	Effective storage capacity	Dam manager
Nunome river (in Yodo river system)	72 m / 322 m (Concrete gravity dam)	15,400,000 m^3	Japan Water Agency

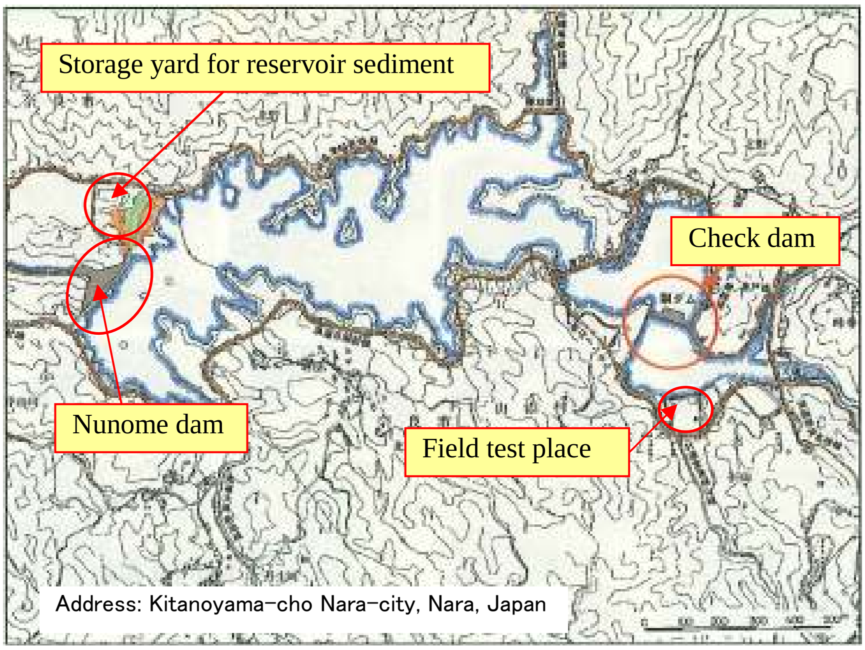

Fig. 6
Outline of the Nunome dam
Périmètre du barrage de Nunome

3CHARACTERISTICS OF RESERVOIR SEDIMENTATION

Dredging of deposited sediment in front of the check dam is regularly executed. When the water level of the check dam is drawn down, the dredging by a backhoe is executed at shallow areas. A cutter suction dredger is used in every three years for relatively deep areas with keeping the water level. Dredged sediments are dried in a large excavated pit made at the park near the reservoir, and trucked to a temporary storage yard (Fig. 6). The locations of dredging in 2000 and 2004 are shown in Fig. 7. Grain size distributions of those sediments are shown in Figs. 8, 9. In case of dredging by backhoe, the fine fraction ratio of 0.074mm or less in grain size (Fc) is in the range of 10-40%. In case of that dredged by cutter suction dredger in 2004, Fc is up to the range of 90%.

The purpose of the field test is to develop the compact system for classifying the reservoir sediments and replenishing them to the downstream river. The reservoir sediments dredged by backhoe in 2000 were used in the test. The Fc of these sediments is in the range of 5-30% as shown in Fig. 8 in which the sediment with Fc being under 10% (Represented by curves 2000-2, 3) is called “coarse dredged sediment”, and the sediment with Fc being nearly 30% (Represented by curves 2000-1) is called “fine dredged sediment”.

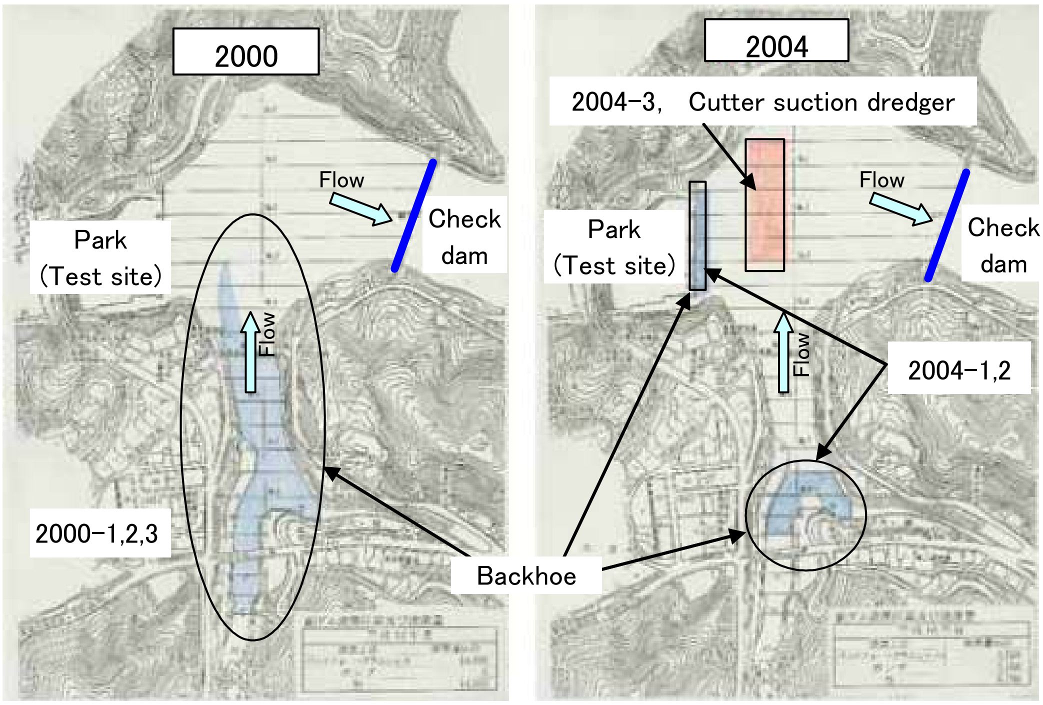

Fig. 7
Dredging locations in the check dam
Zones de dragage du barrage de correction

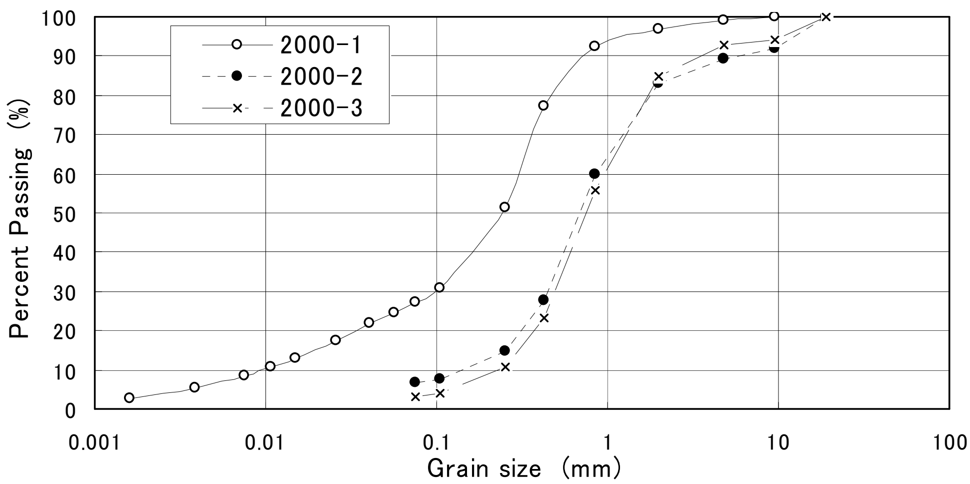

Fig. 8
Grain size distribution of dredged sediment in 2000
Granulométrie des sédiments dragués en 2000

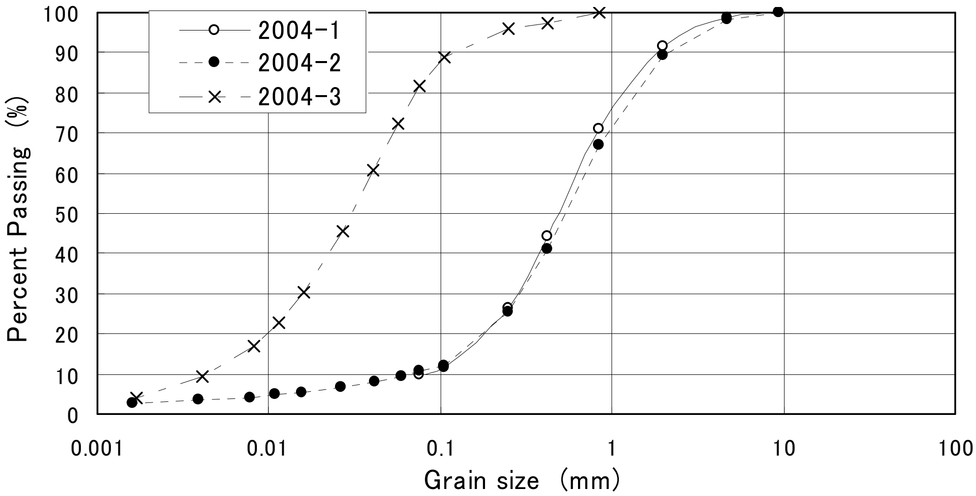

Fig. 9
Grain size distribution of dredged sediment in 2004
Granulométrie des sédiments dragués en 2004

TEST PROCEDURE

The flow chart of the field test is shown in Fig.10. Photo of the field test is shown in Fig. 11. In Fig. 10, (a) to (d) are the soil sampling points, and (e) to (j) are water sampling points for testing, respectively.

The sequence of the field test is described as follows.

1) Dredged sediments from the check dam are trucked and temporally stored next to the treatment plant. Then these sediments are supplied properly into the grand hopper by a pay loader.

2) Dredged sediments pumped up from pump station are sent to the first spiral classifier called “Small Escargot”. Clear water is pumping up from the lake of check dam to the pump station.

3) Dredged sediments and water sending by ejector pump are treated by “Small Escargot” and the recycled coarse sands (called Recycle (1)) are taken out by the screw conveyer.

4) Dredged sediments and water after taken out the coarse sands are sent to “Big Escargot”, and the relatively fine sands are taken out. The classified sands are sent to the Mesh Separator (vibration sieve) for dewatering. The productions of “Big Escargot” are called Recycle (2).

5) Drained water from “Big Escargot” is sent to the lake of the check dam after getting rid of very fine materials in the sedimentation ponds (1) and (2).

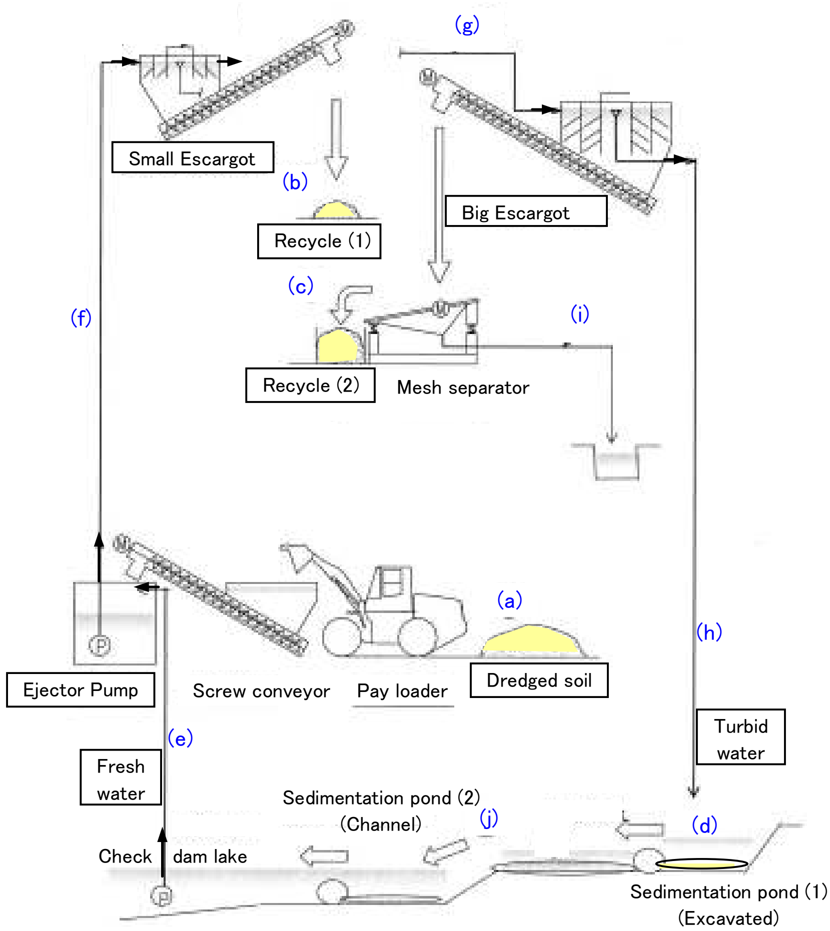

Fig. 10
Flow chart of the field test
Schéma du procédé de l'essai in situ

Fig. 11
Photo of the field test
Photo de l'installation utilisée lors de l'essai in situ

4. TEST RESULT

PERFORMANCE OF THE SYSTEM

The field test was carried out in September 2007. The amount of the recycled sand produced by the system was 108.5 m^3 from 155.5 m^3 of the dredged sediment treated in 12 days. Three cases in the field test were executed as shown in Table 2. Fine dredged sediment was used in Case (1) and (2). Coarse dredged sediment was used in Case (3). In Case (1) and (3), the treatment system was operated normally (as smoothly as possible). In Case (2), the dredged sediment was supplied into the hopper in a massive amount (plentifully; as much as possible).

Performances of the system during the tests are shown in Table 2. The speeds of treatment in Case (1) is lower than Case (3). The reason is that the fine dredged sediment is more cohesive than coarse dredged sediment. Therefore, the screw conveyor under the hopper does not work effectively. The speed of treatment in Case (2) is slightly higher than in Case (3), but the total recycle rate is lower down to 49% in Case(2) compared to 72% in Case(1) and 85% in Case(3).

It was found that to operate this system properly, it is important to adjust supplying speed according to the cohesion of the sediment, which mainly depends on the grain size distribution and the organic matter content.

Table 2
Performance of the reservoir sediment treatment system
Performance du système de traitement des sédiments du réservoir

Case	Type of dredged sediment (volume)	Operation days	Average treatment speed	Recycle volume / ratio		
				Recycle (1)	Recycle (2)	Total
Case (1)	Fine (118.5m^3)	10 days	2.8 m^3/h	61.5m^3 / 52%	24.0m^3 / 20%	85.5m^3 / 72%
Case (2)	Fine (23.5 m^3)	1 days	4.5 m^3/h	8.5m^3 / 36%	3.0m^3 / 13%	11.5m^3 / 49%
Case (3)	Coarse (13.5 m^3)	1 days	4.2 m^3/h	10.0m^3 / 74%	1.5m^3 / 11%	11.5m^3 / 85%
Total	(155.5 m^3)	12 days	-	80.0 m^3 / 51.4%	28.5 m^3 / 18.3%	108.5 m^3 69.7/ %

ROPERTIES OF DREDGED SEDIMENT AND RECYCLED SAND

The grain size distributions (GSDs) are almost the same in Case (1) and (2) as shown in Fig. 12. After the treatment, the Fc (fraction ratio of fine materials under 0.074mm) is reduced from around 30% to less than 10%.

In Case (2), despite the recycle rate was down to 49% as described before, the GSDs of Recycle (1) and (2) are almost the same as in Case (1).

In Case (3) as shown in Fig. 13, the GSDs of Recycle (1), (2) are different from that of Case (1).

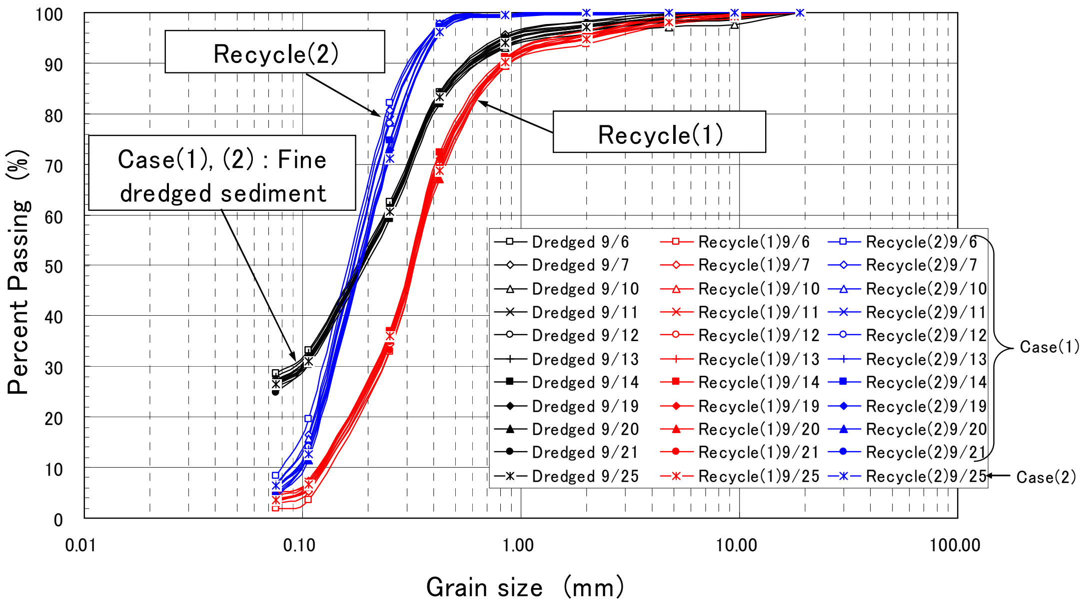

Fig. 12

Grain size distributions

(all data for fine dredged sediment and recycled sand)

Granulométrie (toutes les données concernent des sédiments dragués fins et du sable recyclé)

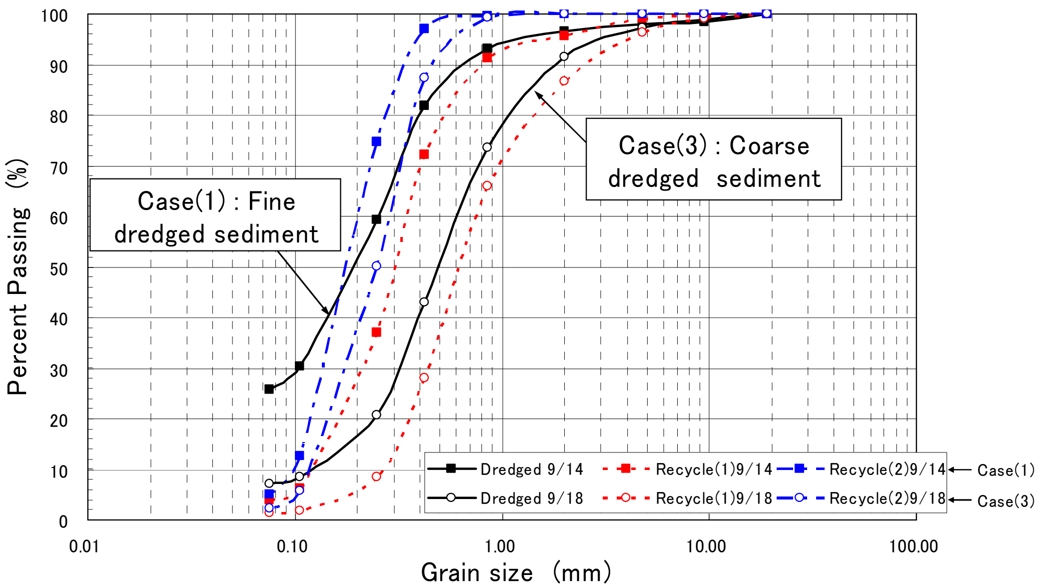

Fig. 13
Grain size distributions
(comparison between fine and coarse dredged sediment)
Granulométrie (comparaison entre sédiments dragués à grain fin et à gros grain)

Figs. 14 and 15 show the grain size frequency and the recycle ratio of each case. Each grain size frequency is sorted out Recycle (1), (2), and discharged with water.

As shown in Fig. 14, the grain size frequency of Case (3) is considerably different from Case (1), but the ratios of Recycle (1) and (2) are almost the same in every range of grain size. This result suggests that the grain size distribution of the recycle sand produced by the treatment system is able to be estimated previously from that of dredged sediment. However, as shown in Figs. 14 and 15, the ratio of recycle may be varied according to the sediment supplying speed.

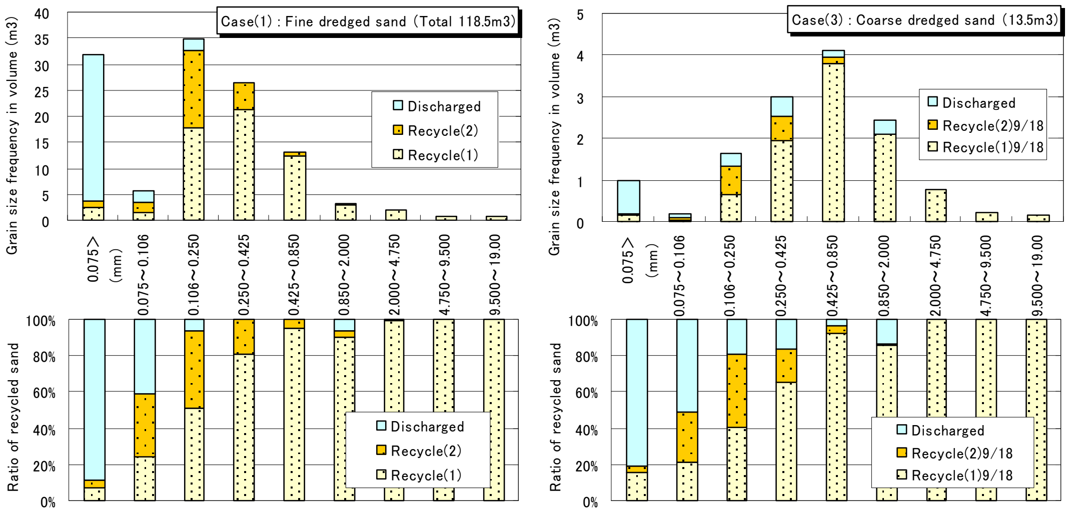

Fig. 14
Grain size frequencies and recycle ratio
(comparison between fine and coarse dredged sediment)
Fréquences granulométriques et taux de recyclage
(comparaison entre sédiments dragués à grain fin et à gros grain)

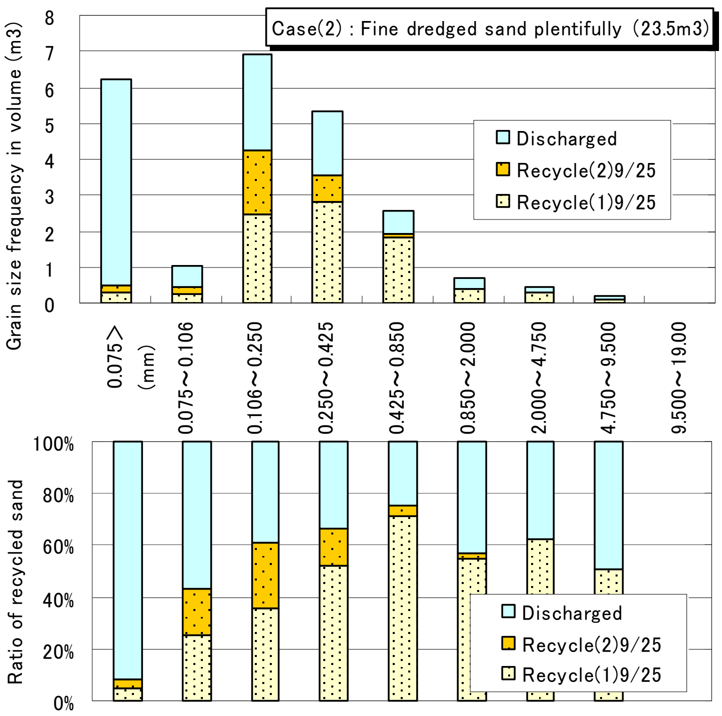

Fig. 15
Grain size frequencies and recycle ratio
(fine dredged sediment, provided plentifully)
Fréquences granulométriques et taux de recyclage
(sédiments dragués de grain fin, fournis en abondance)

Ignition losses of dredged, Recycle (1) and (2) sediment and also the portions of ignition loss after treatment are shown in Fig. 16,

Approximately 6% of organic material in the fine dredged sediment is reduced to 2% in Recycle (1), and 4% in Recycle (2) respectively. In Case (3), initial organic content of coarse dredged sediment is only 2.5%, and this value slightly reduced in Recycle (1), but doesn't reduced in Recycle (2).

The portions of ignition loss after treatment are calculated by multiplying ignition loss and recycled ratio. As shown in the right graph of Fig. 16, it is assumed that approximately 4% of organic matter in fine dredged sediment is discharged with the water.

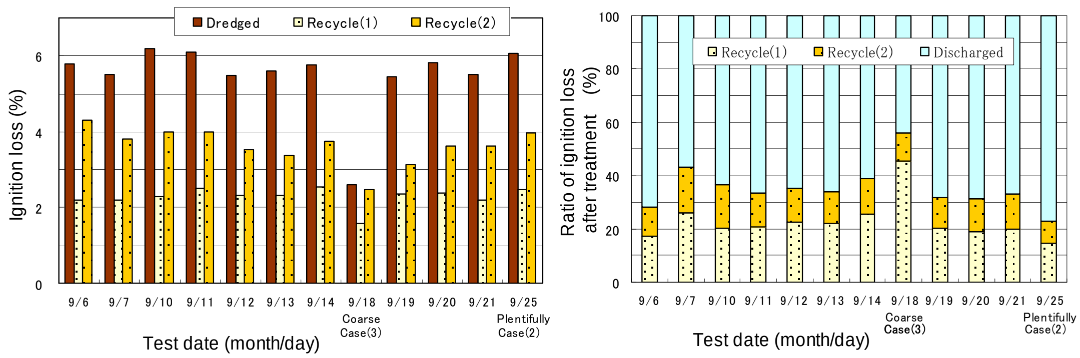

Fig. 16
Ignition loss analyses
Essai de perte au feu (calcination)

PROPERTY OF THE DREDGED SEDIMENT BY ELUTION TEST

The elution test was carried out by stirring 200cc of dredged sediment or recycled sands with 1,000 cc of the clear water in the plastic container in 5 minutes. Discharged water was also tested. Fig. 17 show the test results.

The water turbidity and suspended sediment concentration (SS) of the Recycle (1) and Recycle (2) are reduced to about 10-20% of that of dredged sediment respectively. Similarly, such as chemical oxygen demand (COD) value, the index of organic matter content , the content rate of nitrogen (T-N) , the content rate of phosphorus (T-P), in Recycle (1) and Recycle (2) are reduced to approximately 10-20%.

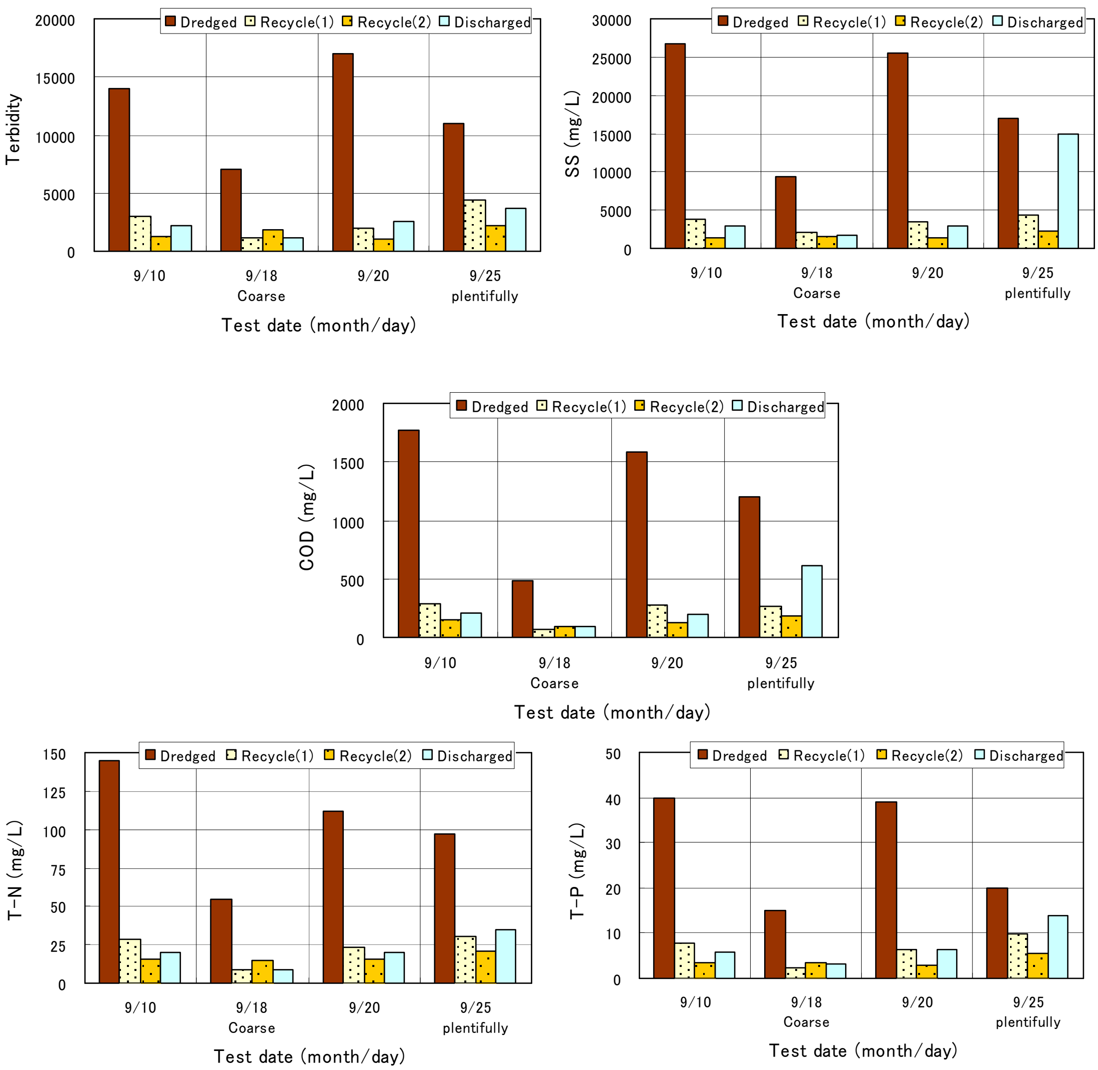

Fig. 17
Elution test results
Résultats du test d'élution

CONCLUSION

In the field test for treatment of reservoir sediment in Nunome dam, several results are found as follows.

1) Performance of the system

The reservoir sediment treatment system successfully worked. It treated dredged sediments at the rate of 3 to 4 m^3 per hour. We found that the production rate is dependent on the cohesion of the sediment mainly depending on the grain size distribution and the organic matter content. The system is able to produce coarse and fine sands approximately 70% to 80% from the dredged sediment.

2) Classification impact

Despite of the type of dredged sediment, the system is able to reduce the content of fine materials under 0.074mm usually causing turbid water problem. It is possible to get high quality sand materials for replenishing to the river from reservoir sediment in consideration of the water turbidity and the nutrients discharge.

3) Washing impact for organic matter and nutrients

The content of COD, nitrogen, and phosphorus can be reduced to between 20% and 10% by using the first spiral classifier “Small Escargot”. It is proved that the washing impact by the ejector worked effectively.

4) Comprehensive evaluation

Generally, in reservoir sediments, there are a lot of very fine materials and nutrients that may cause eutrophication and turbidity problems in reservoirs. It is considered that the ejector pump and the proposed spiral classifiers are very much effective to wash and classify reservoir sediments not only for the replenishment to the downstream river but also for the control of eutrophication or turbidity problems in reservoirs. This study confirmed the ability and feasibility of the proposed new sediment treatment system for reservoir sediment.

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SUMMARY

Sediment replenishment that is to supply dredged sediment artificially to the downstream river is one of attractive solutions to solve reservoir sedimentation problem and to maintain sediment continuity for downstream river from the environmental point of view. In case of the sediment replenishment, it is important to estimate and mitigate water quality changes if the reservoir sediments contain very fine materials which may cause turbidity problems or nutrient discharge.

In this study, we applied a system utilized an ejector pump to collect sediment and two spiral classifiers to produce the appropriate grain sized materials from the sediment. To confirm the effectiveness of the developed treatment system, field tests were executed near a check dam of the Nunome dam reservoir in Yodo river system.

During the field test of 12 days in September 2007, 108.5 m^3 recycled sand was produced from 155.5 m^3 dredged sediment by the system. The sediment which contains about 30% of fine materials under 0.074mm was normally treated at speed of 2.8m^3/hr and the recycle rate is 72%.

After treatment, the very fine materials under 0.074mm were reduced to less than 10% from 30%, and the water turbidity and SS (suspended sediment concentration) obtained by the elution tests were reduced to 10-20% in comparison with the original dredged sediments. The COD (chemical oxygen demand), nitrogen, and phosphorus of the recycle sand were also reduced to 10-20%.

It is considered that the ejector pump and the proposed spiral classifiers are very much effective to wash and classify reservoir sediments not only for the replenishment to the downstream river but also for the control of eutrophication or turbidity problems in reservoirs.

RÉSUMÉ

Le rejet artificiel en aval dans la rivière des sédiments dragués est une solution attrayante pour résoudre le problème du dépôt de sédiments dans le réservoir et pour maintenir la continuité de la sédimentation en aval de la rivière, d'un point de vue environnemental. Dans le cas du rejet des sédiments, il est important d'évaluer et d'atténuer les changements dans la qualité de l'eau lorsque les sédiments du réservoir contiennent des matériaux très fins qui peuvent entraîner des problèmes de turbidité ou de déversement d'éléments nutritifs.

Dans cet essai, nous avons utilisé une pompe à éjecteur pour recueillir les sédiments et deux classificateurs à spirale pour obtenir des matériaux avec une taille de grain appropriée à partir des sédiments. Pour réaliser la phase de développement et mettre au point un système de traitement efficace, des essais pratiques ont été effectués à proximité d'un barrage de correction du réservoir du barrage de Nunome, appartenant au réseau fluvial de la rivière Yodo.

Au cours des essais pratiques qui se sont déroulés sur 12 jours en septembre 2007, 108,5 m^3 de sable recyclé ont été produits à partir de 155,5 m^3 de sédiments dragués par le système. Les sédiments, qui contenaient environ 30 % de matériaux très fins de taille inférieure à 0,074mm, ont été traités à un débit de 2,8 m^3/h et le taux de recyclage obtenu a été de 72 %.

Après traitement, la proportion de matériaux très fins de taille inférieure à 0,074 mm est passée de 30 % à moins de 10 %, et la turbidité de l'eau ainsi que la concentration de sédiments en suspension (SS) obtenue par les tests d'élution a été réduite de 10 à 20 % en comparaison des sédiments dragués avant traitement. La demande chimique en oxygène (COD), la teneur en azote et la teneur en phosphore du sable recyclé ont aussi été réduites de 10 à 20 %.

Nous estimons que la pompe à éjecteur et les classificateurs à spirale proposés sont une solution très efficace pour laver et trier les sédiments des réservoirs, non seulement pour ce qui concerne le rejet des sédiments en aval dans le cours d'eau, mais aussi pour le contrôle de l'eutrophisation et des problèmes de turbidité dans les réservoirs.