Water-saving optimization design of aggregate processing plant and recycled water utilization for producing concrete

Presenter: Dr. Xia Chen

Changjiang River Scientific Research Institute

CONTENTS

01 Introduction and Background

1 Introduction——Aggregate Washing Wastewater(AWW)

■ AWW Generation

DG Aggregate Processing Plant

Yebatan2#Aggregate Processing Plant

- Aggregate processing plant is an essential part of hydropower project, and also of great interest of environmental supervision.
- To avoid dust pollution, water is usually employed to get rid of dust and waste water is genereated.
- The screening and sand manufacturing account for the majority of wastewater.

Projects	**Wulonglong** Langcang River	**Ludila** Jinsha River	Shatuo Wujiang	Shuangjiangkou Dadu River	Wudongde Jinsha River	Xiangjiaba Jinsha River	Yangfanggou Yalong River	Yebatan Jinsha River
Dam height/m	**130.5**	**140**	**106**	**314**	**265**	**273**	**155**	**217**
Production method	**Wet**	Semi-dry	Semi-dry	**Wet**	Semi-dry	**Wet**	**Wet**	**Wet**

Typical AWW Generation Process

1 Introduction-AWW

Characteristics and Treatment

Generation

1.0 to 1.2 times of processed aggregate amount, Suspended solid(SS) concentration (10^4~10^5 mg/L)

Environmental impact

river blockage
water pollution,aquatic accommodation impact

Treatment

Zero waste water discharge policy

Treatment process target: solid-liquid separation. Treatment techniques： Pre-sedimentation, flocculation sedimentation, or multi-stage sedimentation, filter press for sludge and recycle of treated water.

Hydropower Station Name	SK	Ahai	Guandi	Huangjinxia	Nuozhadu	Xiangjiaba	Shuangjiangkou
Maximum concentration (mg/L)	6×10^4	$(6.5\sim7.0)\times10^4$	5×10^4	$(4\sim5)\times10^4$	8×10^4	$(5\sim8)\times10^4$	7×10^4
Discharge standard (mg/L)	＜100	32.5	≤70	＜70	≤70	≤70	≤70

Typical AWW treatment techniques and control parameters

Projects	AWW	SS treated target	Treated techniques	Notes
Wunonglong	550m³/h	＜100mg/L	Pre-precipitation+MGS Clarifier+DH sewage purifier	pH 6~9
A'hai	700m³/h	32.5mg/L	Selective classification separation, combination of mechanical dehydration and natural dehydration	Limestone
Guandi	895m³/h	SS≤70mg /L	Fine sand recovery+flocculation sedimentation+stone powder dehydration recovery+water reuse	PAC/PAM
Huangjinsha	-	＜70mg/L	Pre sedimentation+concentration sedimentation tank+flocculation sedimentation+water reuse	Natural aggregate；onsite 50~60mg/L
Liyang	200m³/h	SS≤70mg /L	Efficient sewage purifier+rubber vacuum belt filter	pH-8.25， SS-34mg/L
Ludila	300m³/h	＜70mg/L	Combination of natural sedimentation and mechanical treatment	PAC,on site SS-52mg/L
Nuozhadu	1200m³/h	≤70mg/L	Fine sand reclaimer+DH high-efficiency sewage purifier+vacuum belt filter treatment process	Langcang river red colloidal particles
Shuangjiangkou	560m³/h	≤70mg/L	Sand settling tank pre-treatment+radial flow sedimentation tank+inclined tube sedimentation tank+filter dewatering	PAC/PAM
Wudongde	810m³/h	≤70mg/L	Mechanical pre-treatment+radial sedimentation tank+mechanical pressure filtration dehydration	PAM, on site SS≤62mg/L
Xiangjiaba	450m³/h	SS≤70mg /L	Sand water separation device+high-efficiency sewage purifier+belt filter treatment process	PAC/PAM
Yangfanggou	910m³/h	≤100mg/L	Mechanical pre-treatment+radial sedimentation tank+mechanical pressure filtration dehydration	PAC

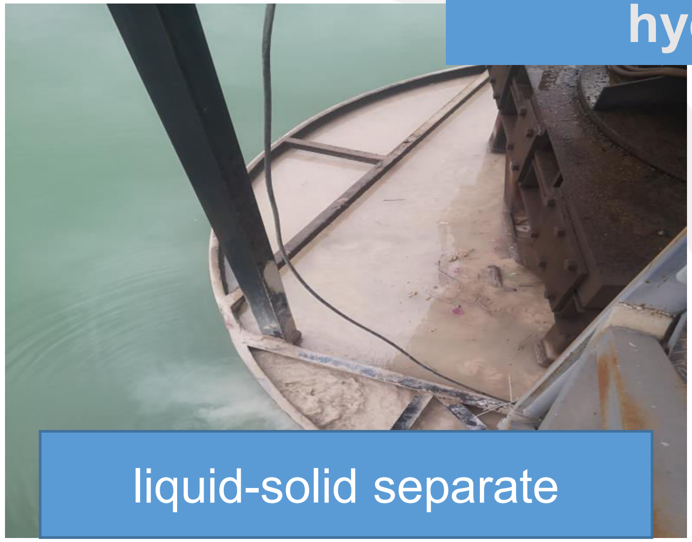
1 Background-Yebatan power station

AWW accumulation

chemical agents added

fully mixed

Typical AWW treatment and recycling process of some large-scale hydro-power station-radial sedimentation tank technique



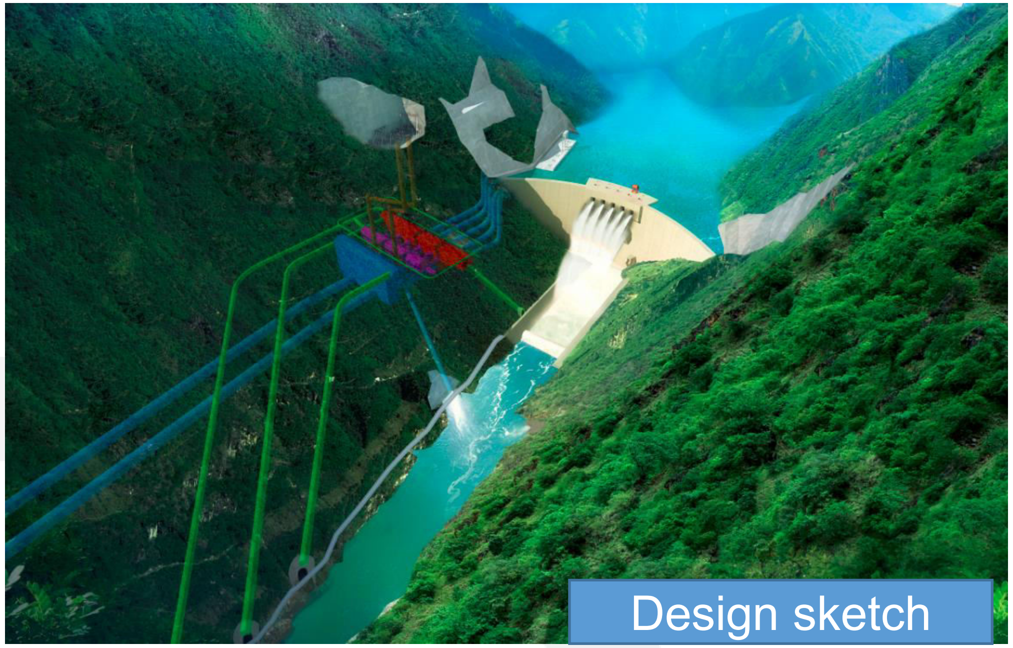
liquid-solid separate

supernatant-reuse

slurry-filtration dehydration

1 Background-Yebatan power station

■ Yebatan hydro-power station aggregate processing plant



Design sketch

Water consumption

low water velocity and poor flushing efficiency

Recycling

absence of AWW reuse water quality control parameters

Chemicals residue

chloride ions residue in water and its adverse effect on concrete

Location

Jinsha river upper stream, high alltitude

Eco-system

Fragile eco-system

- **AWW zero discharge requirement: Concrete amount 3.20 million m^3, AWW generation 700m^3/h, facing enormous technological and cost pressures.**

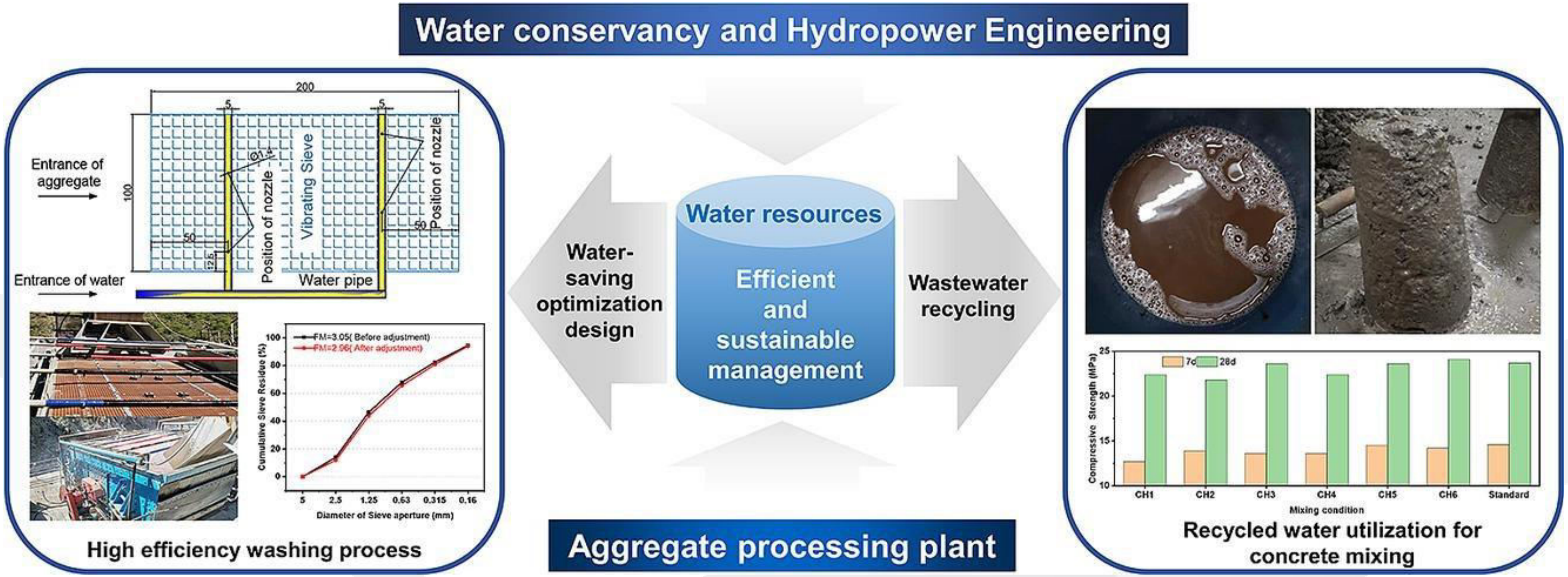
02

Targets and Contents

2 Targets

XVIII World Water Congress
International Water Resources Association (IWRA)

■ Proposed solution



Water consumption: to reduce the amount of wastewater by adopting water-saving measures

AWW recylcing: to be used for concrete mixing and to realize the inner circulation of water resources in hydropower projects.

2 Targets

Water-saving optimization design of aggregate washing system to enhance water efficiency and reduce the scale of wastewater production system

Target

Optimization of washing and spraying device

- The **quantity and arrangement of water outlet points** , the **hydraulic form** of the water outlet, and the **spray angle** of the water flow are all part of the optimization design.

Assessment of the new flushing technology

- Obtain the optimal water-saving washing process, assess for the **field experiment** and **ensure the quality of the aggregate**.

2 Targets

Demonstrate the influence of repeated reuse of the treated AWW and propose the requirement

Target

Flocculation test for AWW

- The law of **chloride ion residue and accumulation** will be demonstrated systematically in the process of repeated reuse of AWW after treatment.

Recycled water for concrete mixing

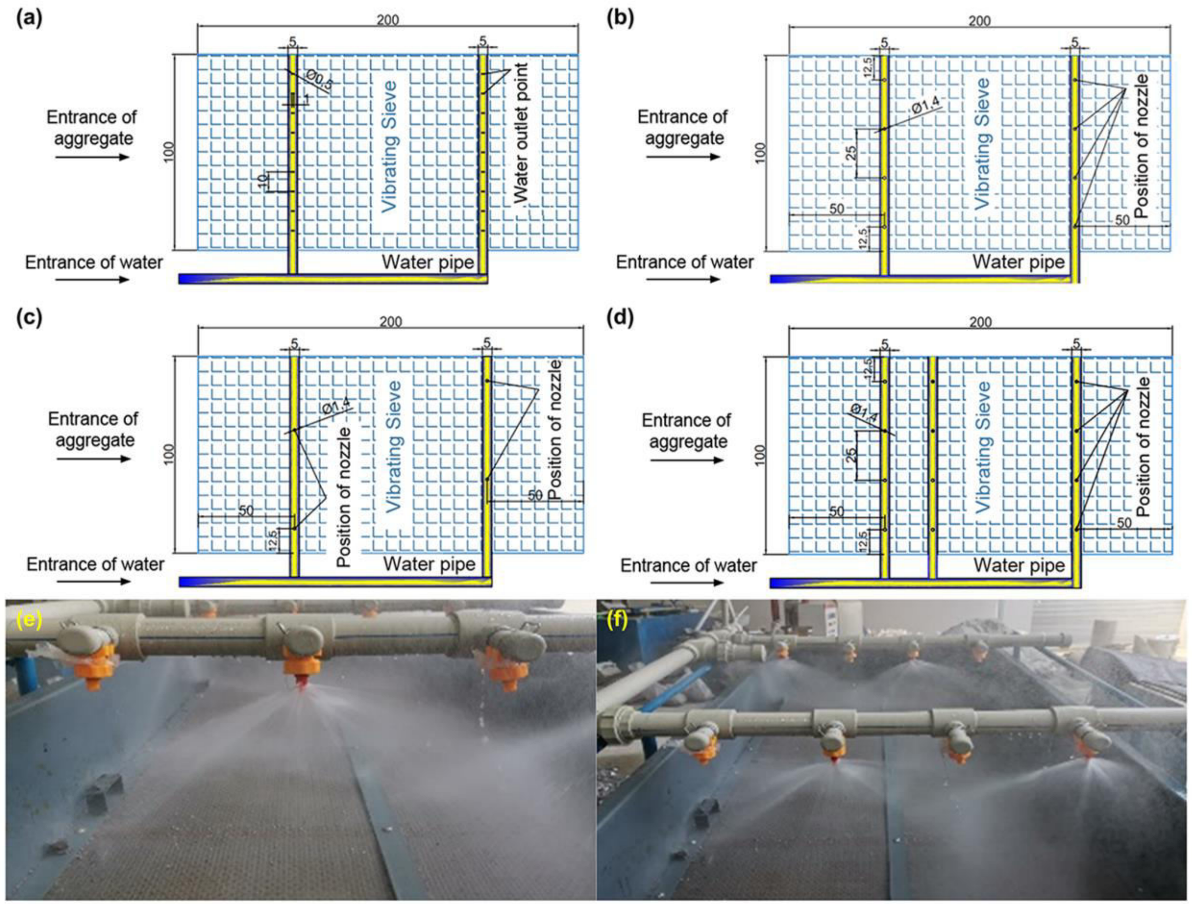
- The influence of wastewater reuse on **fresh concrete and its hardening performance** will be comprehensively studied.
- Clarify the control index of AWW reuse.

2 Research Contents

Construction of aggregate washing device in lab

- **A small-scale aggregate washing device** consisting of a vibrating screen, a washing spray device, and a reservoir was constructed for the test.
- Select **different nozzles** replace the original outlet: **fan-shaped** nozzles, **solid cone** nozzles and **spiral** nozzles
- The deflection of nozzles is set to be 0° (vertical the sieve) and 30° respectively.

Construction of aggregate washing device in lab



Layout of washing device and hydraulic state

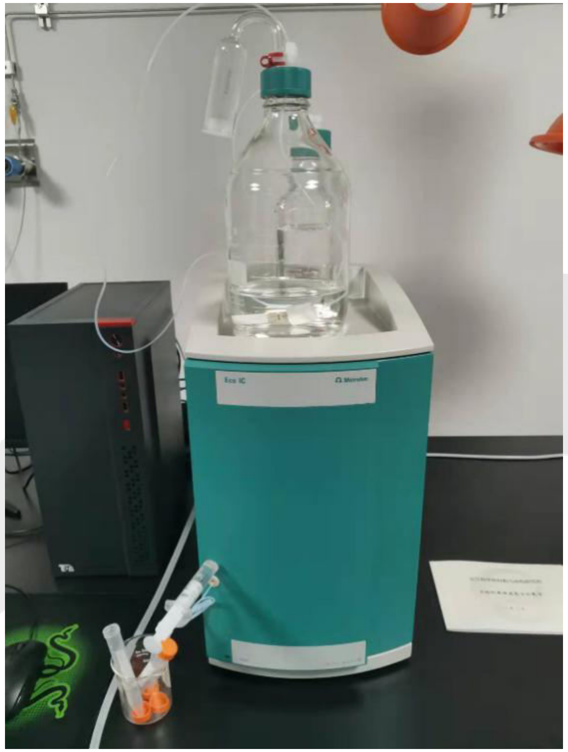
- The specification of the vibrating screen was 2.0 m × 1.0 m, and the diameter of the water pipes was 50 mm; the length was 1.0 m, the interval between the water pipes was 1.0 m; and the water pipes were 30 cm away from the vibrating screen.
- Arrange nozzles for 25% to 30% overlap area to ensure washing effect. Optimization replace two equally spaced tubes with three unevenly spaced tubes.

2 Research Contents

XVIII World Water Congress
International Water Resources Association (IWRA)

Study on characteristics of repeatedly treated AWW

- Flocculants concentrations: Different concentrations of PAC and PAM (PAC:10 mg L^{-1}, 50 mg L^{-1};PAM:10 mg L^{-1},50 mg L^{-1};10 mg L^{-1} PAC+10 mg L^{-1}PAM and 50 mg L^{-1} PAM) were selected as flocculants.
- Sedimentation time: Natural sedimentation 0, 5, 15, 35, 60, 120 min,and flocculating sedimentation was extended to 1440 min, with extra sampling at 180, 360, 540, and 1440 min.
- Wastewater treatment and reuse condition: 80% of the supernatant is obtained by inverted siphon method after settled to be stable, which is used for the next stage of washing aggregate. And repeat the above process.
- Chloride ion residue: water sample needs to pass through a 0.45μm filter membrane before the test.



Experiment and test for concrete mixing

- Tests on the concrete with AWW and tap water were conducted to evaluate the slump test, the setting time test, and the compressive strength. AWW with different SS concentration(28~52360mg/L) was obtained by diluting the initial AWW. The compressive strength test with a load rate of 0.5 MPa s^{-1} at 7 and 28 days was carried out in accordance with GB/T 50081-2019 and performed on three 100 × 100 × 100 m^3 concrete cubes.

Water sample number	pH	SS concentration(mg L^{-1})	Chloridate(mg L^{-1})	Sulphate(mg L^{-1})
CH1	7.73	52360	30.88	54.28
CH2	7.48	23160	24.11	57.22
CH3	7.68	9446	27.84	47.23
CH4	7.65	6235	28.20	44.54
CH5	7.88	1854	22.92	50.92
CH6	7.60	200	28.15	44.30
Tab water	7.03	28	24.91	45.50
Plain concrete (DL/T 5144-2015)	＞4.0	＜5000	＜2700	＜3500

03

Results and Discussion

3 Results and Discussion

Washing parameters and washing efficiency

- Washing Efficiency (WE) is an indicator to assess the consumption of water for a ton of aggregate under the specified washing process conditions.

$$\mathrm{WE}\ (\mathrm{m^3/t}) = \frac{The\ volume\ of\ water\ consumption\ in\ aggregate\ washing\ (m^3)}{the\ quantity\ of\ aggregate\ (t)} \times 100\%$$

- Fineness modulus (FM) is calculated as the ratio of the sum of accumulated sieve residue percentages for each sieve used in the screening test to the corresponding sieve residue. This index is considered a significant measure of aggregate quality. A1, A2, A3, A4, A5, A6 are the percentage of cumulative screen residue on screen of 5, 2.5, 1.25, 0.63, 0.315, 0.16mm.

$$\text{Fineness Module} = \frac{A2 + A3 + A4 + A5 + A6 - 5A1}{100 - A1}$$

- During the simulation experiment, the flushing time was controlled to be fixed as 15 s, and the aggregate amount was changed at the same time to ensure that WE of the existing flushing condition was 1 m^3/t and that of other conditions was 0.5 m^3/t.

3 Results and Discussion

Aggregate quality and SS concentration

- Different parameters of washing process are coded as C1 to C10. C1 is to simulate the existing flushing condition. C2 to C10 use different nozzles, deflection angles and pipe layouts.

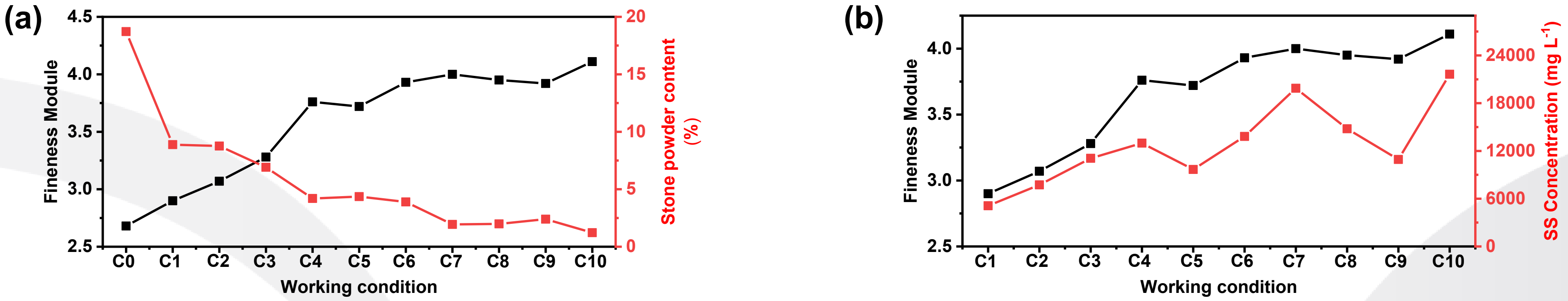
Condition	Nozzle Type	Hydraulic form	Deflection	Layout of water pipes	Water outlet points	Water pressure (MPa)	Washing time(s)	Water used (m^3/h)	WE (m^3/t)
C1	-	Jet-flow	-	Double	40	0	15	11.5	1
C2	Fan-shaped	Fan-shaped	0°	Double	8	0.25	15	5.6	0.5
C3			30°	Double	8	0.25	15	5.6	0.5
C4				Triple	12	0.15	15	6.66	0.5
C5	Cone-solid	Cone	0°	Double	8	0.38	15	4.4	0.5
C6			30°	Double	8	0.38	15	4.4	0.5
C7				Triple	12	0.2	15	6.1	0.5
C8	Spiral	Conical turbulence	0°	Double	4	0.2	15	6.5	0.5
C9			30°	Double	4	0.2	15	6.5	0.5
C10				Triple	6	0.15	15	6.5	0.5

3 Results and Discussion

XVIII World Water Congress
International Water Resources Association (IWRA)

Aggregate quality and SS concentration

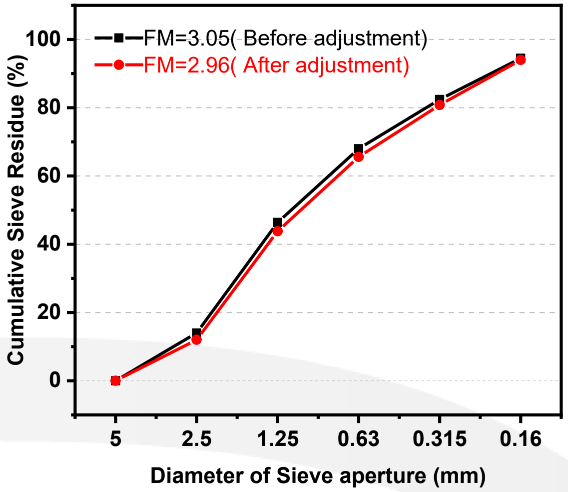
- The fineness modulus of C2 to C10 was higher compared to C0 and C1, while the initial stone powder content of 18.7% decreased significantly after optimizing the washing process. This indicates a notable improvement in aggregate quality. (Fig a)



- There was a positive correlation between the fineness modulus and SS concentration, which suggests that stone powder was effectively removed from the aggregate surface and transferred to the washing water.(Fig b)
- Refining the nozzle arrangement allowed for improved aggregate quality with 50% less water consumption, indicating the possibility of substantial water saving.

3 Results and Discussion

Field experiment



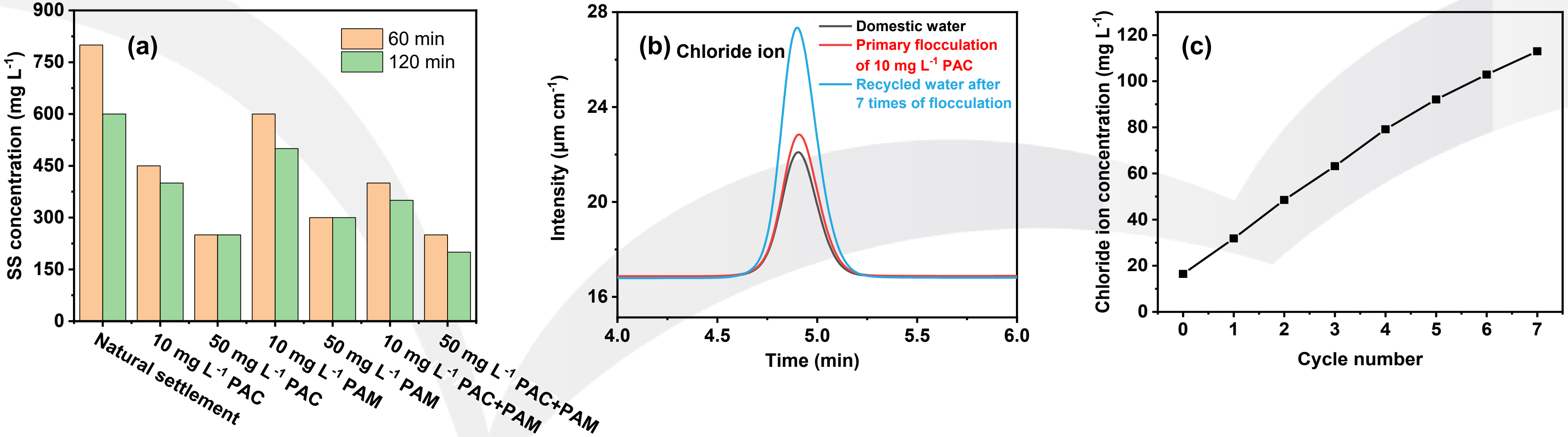
- The optimized rinsing device can ensure that the aggregate quality meets the requirements while reducing the water consumption by 50%.
- The feasibility of applying the new optimized technology in aggregate washing system is verified.

3 Results and Discussion

XVIII World Water Congress
International Water Resources Association (IWRA)

Flocculation test for AWW

- The addition of PAC and PAM in a single or compound way do have effect on suspended solids sedimentation, but the benefit of mixed addition is limited considering the economic benefit. PAC has stronger flocculation effect than PAM under different flocculant addition.(Fig a)
- The content of chloride ions in the supernatant after the natural settlement of AWW did not increase compared to domestic water. This finding suggests that aggregate is not the source of chloride ions.
- The chloride ion concentration of recycled water just exceeded 100 mg L^{-1} after 7 cycles. (Fig b and Fig c)



3 Results and Discussion

Recycled water for concrete mixing

- According to the Specification for Hydraulic Concrete Construction (DL/ T 5144-2015), the chloride ion concentration should be ≤1200 mg L^{-1} in water for concrete mixing (reinforced concrete), while the Standard of Water for Concrete (JGJ63-2006) requires the chloride ion concentration to be ≤500 mg L^{-1} in water for concrete mixing (pre-stressed concrete).

- The concentration of chloride ions in the recycled water remained far below the prescribed standards, indicating that the accumulation of chloride ions caused by dosing would not have side effects on subsequent concrete mixing.

Standard		Chloridate(mg L^{-1})
Specifications for construction planning of water resources and hydropower projects SL 303-2017	Construction water	-
	Concrete mixing water	**≤1200(Reinforced concrete) ≤3500(Plain concrete)**
	Agggreate washing water	＜3500
Specifications for hydraulic concrete construction（DL/T 5144-2015）	Reinforced concrete	**＜1200**
	Plain concrete	**＜3500**
Standard of water for concrete（JGJ 63-2006）	Prestressed concrete	≤500
	Reinforced concrete	≤1000
	Plain concrete	≤3500

3 Results and Discussion

XVIII World Water Congress
International Water Resources Association (IWRA)

Recycled water for concrete mixing

- The setting time shows a first decline and then an increase trend with the decrease of SS concentration in the mixing water.
- The initial setting of concrete is distinctly delayed under CH1 conditions, while the initial setting times of water-mixed concrete display an advancement under other conditions.

Water sample number	SS concentration (mg L^{-1})	Slump /loss(mm/%)		Air Content/loss(%/%)		Setting time(h: min)	
		0h	1h	0h	1h	Initial setting	Final setting
CH1	52360	45/0	30/33	4.5/0	3.6/23	20:45	27:34
CH2	23160	52/0	38/27	4.7/0	3.8/19	14:17	27:57
CH3	9446	50/0	37/26	5.2/0	3.9/25	12:48	26:47
CH4	6235	48/0	34/29	5.4/0	3.8/30	12:05	26:14
CH5	1854	52/0	35/33	5.5/0	3.9/29	13:13	25:28
CH6	200	50/0	35/30	5.5/0	3.8/13	11:54	25:40
Standard	28	55/0	37/33	4.5/0	3.8/16	15:20	26:42

3 Results and Discussion

XVIII World Water Congress
International Water Resources Association (IWRA)

Recycled water for concrete mixing

Water sample	Compressive Strength(MPa)	
	7d	28d
CH1	12.7	22.4
CH2	13.9	21.8
CH3	13.6	23.6
CH4	13.6	22.4
CH5	14.5	23.6
CH6	14.2	24.1
Standard	14.6	23.7

- The maximum reduction of the compressive strength of recycled concrete samples was less than 2 MPa when compared to the benchmark concrete.
- AWW can be used for concrete production to reduce water construction and AWW treatment costs, and the recycled water's maximum SS concentration should not exceed 1800 mg L^{-1} to maintain optimal compressive strength and proper setting time .

04

Conclusions

4 Conclusions

XVIII World Water Congress
International Water Resources Association (IWRA)

- A new and efficient water-saving washing design was developed for aggregate processing plants, which reduced water consumption by **up to 50%** and ensure good quality of aggregate.
- The accumulation of chloride ions caused by the addition of PAC has **no side effects** on the subsequent reuse.
- SS concentration in treated AWW used for concrete mixing should **not exceed 1800 mg L^{-1}**.

Construction and Building Materials 396 (2023) 132381

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

ELSEVIER

Water-saving optimization design of aggregate processing plant and recycled water utilization for producing concrete

Qi Lu [1], Zeyu Fan [*,1], Xian Zhou, Ziling Peng, Zhuo Fan Gao, Shanshan Deng, Wei Han, Zhongwu Jin, Xia Chen [*]

Changjiang River Scientific Research Institute, Research Center of Water Engineering Safety and Disaster Prevention of Ministry of Water Resources, Wuhan 430010, China

ARTICLE INFO

Keywords:
Water-saving
Recycled water utilization
Aggregate processing
Aggregate washing wastewater
Concrete mixing

ABSTRACT

Water resources utilization in large hydropower projects is primarily allocated to aggregate washing. Current washing devices are inefficient and lead to serious waste of water. Thus, a novel washing device is designed by optimizing outlet point layout and hydraulic form. The device's various nozzles, particularly the spiral ones, offer greater rinsing coverage and improved washing efficiency with multiple interfacial sprays. Compared to conventional methods, the new washing process has reduced water usage by half, and its effectiveness has been verified in Yebatan hydropower station's aggregate processing system. Subsequently, the feasibility of using recycled water for concrete mixing is verified. Recycled water may impair concrete performance due to Cl^- accumulation after flocculation and high suspended solids concentration. Experiments confirm that Cl^- and under 1800 mg L^{-1} suspended solids concentration do not significantly impair concrete performance. This work optimizes the utilization of water resources in aggregate processing from source and terminal.

1. Introduction

The growing emphasis on water conservancy and hydropower projects has led to a significant increase in the demand for concrete and aggregate [1]. Accordingly, aggregate processing plants and concrete mixing plants are being built as necessary supporting facilities to meet engineering requirements [2,3]. For instance, the Yebatan Hydropower Station in the upper reaches of Jinsha River requires approximately 3.2 million m^3 of concrete, with aggregate consumption accounting for around 70% to 80% of the total. Currently, most aggregate processing plants adopt the wet production method to minimize dust and reduce environmental pollution on construction sites [4,5]. In China, the water depletion and water pressure of aggregate processing plants has proposed reference index such as specifications for construction planning of water resources and hydropower projects (SL 303–2017). Nevertheless, aggregate washing on construction sites requires an average water usage rate that is 1.2 times higher than the weight of sand and aggregate, significantly draining water resources and increasing the cost of aggregate processing plants [6,7]. Most wastewater generated from aggregate washing is characterized by high suspended solids (SS) concentration [8]. Direct discharge of aggregate washing wastewater (AWW) with high SS concentration brings out severe ecological and environmental risks [9]. Meanwhile, water conservancy and hydropower projects are facing huge technical and cost pressures of zero wastewater strategy [10]. The current dilemma of water utilization in aggregate processing plants, which involves water consumption and wastewater disposal, is a critical issue that requires a multi-faceted approach to address. To effectively solve this problem, there are two main aspects that need to be given attention and addressed. Firstly, it is essential to reduce the generation of wastewater fundamentally by adopting water-saving measures at the water source [11]. The second is the efficient treatment and recycling of sand and gravel wastewater to realize the inner circulation of water resources in hydropower projects [12].

Our field surveys reveal the current washing process of aggregate is simple and inefficient. Many circular holes with a diameter of 5 mm evenly distributed on the outlet pipe of the existing flushing system. Consequently, the jet hydraulic form of each water outlet point is characterized by a low water velocity and poor flushing efficiency, which requires a large amount of water to meet the desired output. Additionally, the traditional arrangement of water outlet points does not

* Corresponding authors.
E-mail addresses: fanzeyu717728@163.com, chenxia@mail.crsri.cn (X. Chen).
1 Co-first author: These authors contributed equally to this work.

https://doi.org/10.1016/j.conbuildmat.2023.132381
Received 26 May 2023; Received in revised form 14 June 2023; Accepted 1 July 2023

证书号第15908916号

实用新型专利证书

实用新型名称：一种高浓度水电砂石废水SS浓度在线快速检测装置

发 明 人：范雄安;李家正;王文学;李富兵;陈霞;赵凯;王继孝;赵恒
周显;范泽宇;万沙;彭子凌

专 利 号：ZL 2021 2 1781232.7

专利申请日：2021年08月02日

专 利 权 人：华电金沙江上游水电开发有限公司叶巴滩分公司
长江水利委员会长江科学院

地 址：627153 四川省甘孜藏族自治州白玉县盖玉乡

授权公告日：2022年03月01日　　授权公告号：CN 215917197 U

国家知识产权局依照中华人民共和国专利法经过初步审查，决定授予专利权，颁发实用新型专利证书并在专利登记簿上予以登记。专利权自授权公告之日起生效。专利权期限为十年，自申请日起算。

专利证书记载专利权登记时的法律状况。专利权的转移、质押、无效、终止、恢复和专利权人的姓名或名称、国籍、地址变更等事项记载在专利登记簿上。

局长
申长雨

2022年03月01日

第1页（共2页）

证书号第18110541号

实用新型专利证书

实用新型名称：一种高效节水的新型水电砂石骨料冲洗系统

发 明 人：李家正;曾乾礼;陈霞;王文学;范泽宇;李富兵;周显;赵凯
王继孝;赵恒;彭子凌;高卓凡;高志扬;吕兴栋;郭文康

专 利 号：ZL 2022 2 1214539.3

专利申请日：2022年05月20日

专 利 权 人：长江水利委员会长江科学院
华电金沙江上游水电开发有限公司叶巴滩分公司

地 址：430000 湖北省武汉市江岸区黄浦大街23号

授权公告日：2022年12月23日　　授权公告号：CN 218108579 U

国家知识产权局依照中华人民共和国专利法经过初步审查，决定授予专利权，颁发实用新型专利证书并在专利登记簿上予以登记。专利权自授权公告之日起生效。专利权期限为十年，自申请日起算。

专利证书记载专利权登记时的法律状况。专利权的转移、质押、无效、终止、恢复和专利权人的姓名或名称、国籍、地址变更等事项记载在专利登记簿上。

局长
申长雨

2022年12月23日

第1页（共3页）

THANKS FOR YOUR ATTENTION

Email: chenxia@mail.crsri.cn