Wear Control Study of a Long Distance In-line Chute Conveying Concrete

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Abstract. In order to study the wear of concrete on the wall surface when it flows in the chute, the numerical simulation software Fluent was used to analyse the erosive wear of concrete on the chute, the concrete is in a laminar flow state in the chute, according to the pressure distribution of concrete on the chute under the influence of the cloud diagram as well as gravity, the bottom area of the chute is the main contact surface with the concrete, which is also the main location where the wear occurs. Using the DPM particle model, simulate the erosion wear of concrete in the chute, the wear occurs in the same location with the aggregate accumulation area, the wear is serious in the bottom of the area near the centre axis, chute slope and inflow velocity can affect the wear of concrete on the chute, and based on the Hut collision theory that the larger the aggregate particle size, the more serious the destruction of the wall, the aggregate particle size will be controlled to within 10-20mm. In order to extend the service life of the chute, it is proposed to optimise the chute shape design to reduce the chute replacement rate.

Keywords: Concrete flow characteristics, Bingham open channel model, laminar flow, wall wear

1 Introduction

With the deepening of China's water conservancy project construction， the demand for concrete construction is becoming more and more huge, chute conveying concrete has become an emerging concrete conveying method due to its advantages of high conveying efficiency and low cost, and for the actual construction of a gently sloping chute built in a water conveyance tunnel. Wall wear will destroy the structural durability and stability of the conveying channel, and will also cause concrete segregation and other hazards. Therefore, it is of great importance to study the control of concrete wear in the chute in order to improve the service life of the chute and the

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quality of concrete transport.

1.1 Open channel flow of concrete

During the flow of freshly mixed concrete, particles will be repelled by various physicochemical forces with the wall to appear voids, which are filled by the suspension[1] and is called the shear slip layer, Le,D[2] On the experimental study of the flow mechanism of concrete with a semicircular nullah channel, in which the migration law of concrete aggregate is the same, after collision with the wall, it will tend to the centre axis of the chute, and the thickness of the slip layer depends on the diameter and concentration of the particles. The inside of the concrete consists of sand and stone aggregates and cement slurry, and under the action of shear stress, the coarse particles will migrate from the place of high shear rate to the place of lower shear rate[3].The shear rate is highest near the wall, and the flow mechanism of this shear slip layer is the same whether in open channel flow or pipe flow.

1.2 Forms of concrete flow

The flow state of concrete in the pump pipe is mainly manifested as[4] For "lubrication layer + piston flow" and "lubrication layer + shear slip layer + piston flow" two forms, while the concrete in the chute flow, there is a free surface, that is, there is no piston flow of this form of flow, more is to "lubrication layer + shear slip layer" flow. Lubricating layer + shear slip layer" flow.

Turbulence is the most common flow phenomenon in engineering, as opposed to laminar flow, where the fluid is discontinuous and the materials are not uniformly mixed during the flow. The law of concrete flowing in turbulent form is difficult to capture and there is no suitable intrinsic model to characterise the turbulent motion of concrete, in this study concrete is considered as a steady laminar flow.

The concept of laminar flow originated from the Reynolds experiment[5], when the concrete is in a lower flow rate state, and the aggregates in their respective flow layer are in a continuous and uniform flow, each other unadulterated, it can be recognized that the concrete is in laminar flow. The open channel flow of concrete is similar to the pipeline flow, in the open channel flow of concrete only gravity as a driving force, and the restricted flow of the pipeline is different, the open channel flow of concrete has an unpressurised free surface, in the stable flow, the free surface development direction will be the same as the direction of gravity drive.

At present, for the concrete of the nullah flow wear research is less, mostly to the concrete of the pipeline flow wear is dominated, in addition to the research in this area is of great significance.

1.3 Concrete long distance chute flow

Concrete chute flow is different from the pump transportation, the concrete through the chute occurred since the chute type flow, due to the existence of free surface, direct contact with the air to react, with the flow of the depth of the bottom of the cave, the temperature rises, the humidity decreases, the dust increases, it is easy to exacerbate the hydration reaction of the concrete, which is prone to lead to the occurrence of the concrete initial condensation phenomenon. As shown in Figure 1.

the planing surface of the inclined shaft branch hole, it takes about 15min for the concrete to flow from the hole to the bottom of the hole.Figure 2 shows the chute transportation system and rail transportation system of the branch hole, and the concrete is mainly transported through the chute, and the concrete is mainly transported through the chute.

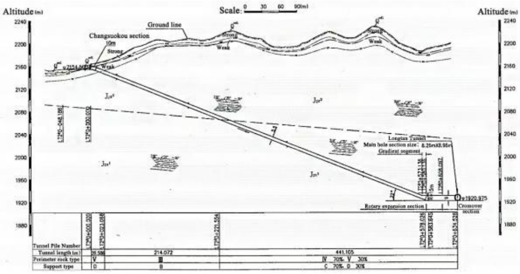


Fig. 1. Planing surface of inclined shaft tunnel **Fig. 2.** Transportation system of the branch hole

2 Wear mechanism of concrete flow

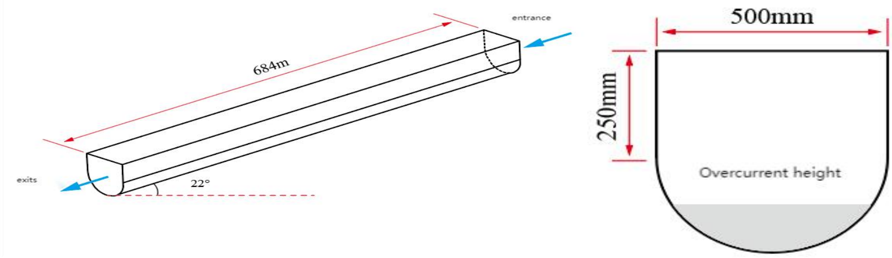
Concrete chute transport process, the transport resistance can not balance the gravitational potential energy of the paste, as the entrance to the beginning of the formation of the accelerated flow state, accompanied by an increase in the flow rate of concrete, exacerbating the wall wear, with the slowing down of the chute slope, the transport resistance can be gradually balanced gravitational potential energy, reducing the wear of the chute, due to the needs of the design of the inclined shaft branch hole, the chute slope must be consistent with the slope of the inclined shaft. In order to study the water diversion process in Dianzhong a tunnel inclined shaft concrete chute transport, as shown in Figure 3, for the long-distance chute sketch, by 2m long U-shaped steel plate stacked, chute inclination angle of 22 ° uniform.

Fig. 3. Single chute machining diagram **Fig. 4.** Chute bending and pressing processing diagram

Chute wall breakage is mainly in the form of erosion wear and impact wear, concrete mortar, aggregate, chute material are the main factors leading to chute breakage[5] As shown in Figure5, the bottom of the chute is damaged by the slurry. As shown in Figure 6-7 for the wear damage of the slurry on the bottom of the chute, the smooth part is the result of erosion wear and the depressed pits are the result of impact wear of the coarse aggregate. The concrete resistance along the conveying process is positively correlated with the slurry mass concentration and is influenced by the cement material, which will cause different degrees of corrosion on the chute. From the formula[6][7] it can be seen that as the flow rate increases, the shear stress of the concrete at the chute boundary becomes greater, which increases the wear of the chute.

$$\bar{\tau} = \frac{f}{8}\rho V^2 \tag{1}$$

$\bar{\tau}$ is the average boundary shear stress, f is the coefficient of friction (determined by material roughness), and ρ is the concrete density.



(a) (b)

Fig. 5. Sketch of the chute model

Fig. 6. Chute wear

Fig.7. Waterproofing sheet breakage

3 Intrinsic modeling of fresh concrete

Freshly mixed concrete is a non-Newtonian thixotropic material, because cement and other cementitious materials in contact with water, hydration reaction occurs[8], hydration reaction occurs in this regard, with the intensification of the hydration phenomenon, the concrete undergoes incipient hardening, and the thixotropy of the concrete will gradually decrease, assuming that concrete is a continuous homogeneous single-phase flow material, the concrete has elastic properties before flow, and after the onset of flow, the concrete has visco-plasticity. Its flow behaviour can be characterised by the Bingham model[8] :

$$\tau=\tau_0+\mu\gamma \qquad (2)$$

Where τ for the shear stress, μ for the plastic viscosity, γ for the shear rate, τ_0 for the yield stress, when the shear stress is less than the yield stress, the concrete is solid; when the shear stress is greater than the yield stress, the concrete is liquid, began to flow according to the law of non-Newtonian fluids of plastics, and in the process of the flow of viscosity is mainly affected. The size of the yield stress determines the flow properties of concrete, plastic viscosity determines the flow stability of concrete.

4 Numerical simulation

Numerical simulation using Fluent software[9] The laminar flow model is selected, the inlet end is set as the velocity inlet, the outlet end and the free boundary of the chute are set as the pressure outlet boundary, and the H-B model is used to characterise the flow characteristics of the concrete in the solver, and the power law exponent is set to 1. According to actual engineering practice, in order to ensure that the flow rate of concrete reaches 84m^3/h (the flow rate Q is the product of the spillway cross sectional area and the inlet velocity, i.e. Q = SV), the spillway height of concrete is unified as 120mm and the inlet velocity is 0.65m/s. The overflow height of concrete is unified as 120mm and the inlet velocity is 0.65m/s. The yield stress and plastic viscosity are taken as variables to investigate the wear of concrete on the chute during the flow process.

Due to the complexity of concrete flow during chute transport, the constructed model is simplified and the following assumptions are made about the model:

(1) Concrete is considered as a continuous incompressible type of fluid and its flow properties are characterised by the Bingham model;

(2) The variation in cross-section at the overlap of the chute is ignored and the chute is treated as a straight open channel with a uniform cross-section;

(3) Neglecting the effect of hydration reaction on concrete flow.

4.1 Concrete erosion wear

The concrete is considered as a Bingham fluid, and using the VOF finite volume method, the concrete is set as the main phase and the air is set as the secondary phase, and the air fills the chute in the initial phase [10]. Driven by gravity, the concrete flows along the bottom of the chute in a uniform laminar flow, and the simulation results are shown in the cloud diagrams of Figure 8, Figure 9 and Figure 10, combined with the volume fraction cloud diagram 6, in the upper part of the concrete flow field for the air phase in the middle of the concrete flow field in the middle part of the flow rate of the maximum. Concrete in the chute flow process, due to gravity-driven self-slip, the pressure difference on the wall is relatively small, negligible, the pressure on the bottom of the chute is the largest, so the chute erosion and wear mainly occurs at the bottom of the chute.

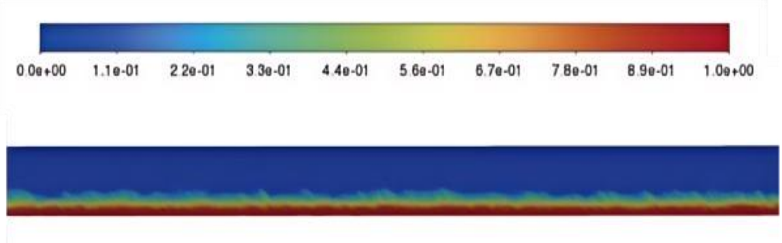
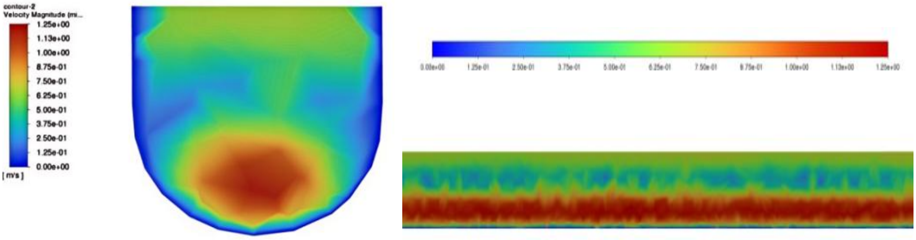
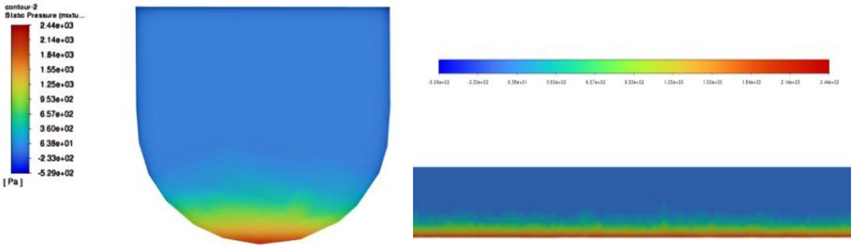


Fig.8 . Volume fraction cloud image



(a) (b)

Fig.9 . Cross-sectional pressure cloud



(a) (b)

Fig. 10. Cross-sectional pressure cloud

Effect of yield stress on flow velocity. With the growth of yield stress, concrete paste and aggregate within the composition of the "flocculent network" will be more compact, the need for greater external force to keep the concrete in the flow state, the loss of mechanical energy in the flow process will gradually increase, as shown in Figure11-12 the flow rate will be gradually reduced to protect the chute against erosion and wear is more obvious.

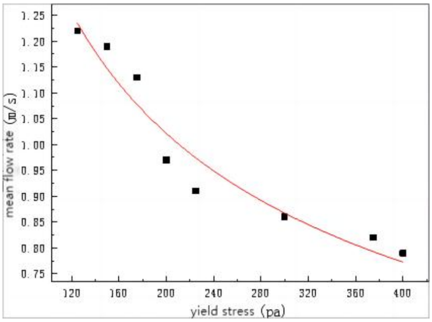


Fig.11. Yield stress versus average flow rate

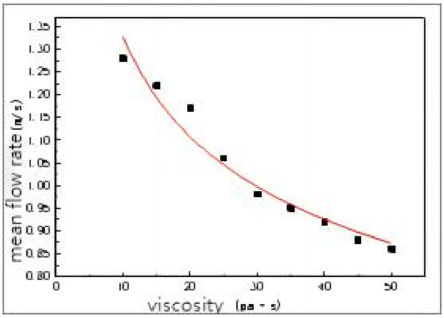


Fig. 12. Viscosity versus average flow rate

Effect of plastic viscosity on flow rate. Plastic viscosity is an important factor in maintaining the laminar flow of concrete, through the relationship between the Reynolds number, the greater the plastic viscosity, the more stable the flow of concrete. The higher the plastic viscosity, the lower the flow rate, the lower the erosion wear on the channel wall.

4.2 Modeling

Erosion wear is the material damage caused by the impact of fluid or solid particles on the wall surface at a certain speed, in this study, Fluent is used to simulate the chute erosion wear[11] It is mainly divided into 3 steps: (1) Turning on the continuous phase solution, the fluid is considered as a continuous phase, and its control equations are determined by the N-S equations in Chapter 3 section. (2) Particle trajectory tracking, in the DPM model, the particles are considered as discrete phases, and the Euler-Lagrange method is adopted to solve the force equation of the solid particles under the Lagrange coordinate system to obtain the trajectory of the particles. (3) Calculation of the erosion rate, the velocity, number and angle of the particles hitting the chute wall are substituted into the Finnie erosion model calculation solver provided with Fluent to obtain the erosion rate of the chute wall.

The particle erosion wear model defined in Fluent has the form:

$$ER = \sum_{p=1}^{N_{particles}} \frac{m_p C(d_p) F(\alpha) u_p^{b(u_p)}}{A_{face}} \quad (3)$$

Among them, $C(d_p)$ represents the function related to the particle diameter; $b(u_p)$ represents the function related to the particle collision velocity; A_{face} (㎡) represents the area of the wall calculation unit; $N_{particles}$ represents the number of collisions of particles on the area of the unit; ER is the erosion rate expressed in kg/(㎡-s). The functions $C(d_p)$, $F(\alpha)$ and $b(u_p)$ can be customized by the user. Fluent gives five input methods for the collision angle function, including constant, linear, segmented linear, simple polynomial, and the erosion rate will be stored in the wall calculation unit after calculation.

Fluent18.0 has added new erosion models such as Finnie, McLraury and OKa, and users can adopt default parameters to record the trajectory of particles and the number of collisions of particles on the wall, and the Finnie erosion model will be used in this study.

The DPM is a numerical model based on the Euler-Lagrange method, which defaults to a low volume fraction for solids and requires the volume fraction of the solid phase to be strictly controlled below 12%, but there is no strict control on the mass fraction of the solid phase. Interactions between particles are not considered, but various forces on the particles in the flow field need to be considered.

Fluent solves the trajectories of discrete-phase particles by integrating the differential equations of the forces on the particles in the Raschel coordinate system. [58] The main forces in the flow field are gravity, buoyancy, drag, pressure gradient force, additional mass force and Basset's force (Basset). The equilibrium equations for the forces on the particles are:

$$\frac{du_p}{dt} = F_D(u - u_p) + g(\rho_p - \rho) + F \tag{4}$$

$$\begin{aligned} F_D &= \frac{18\mu}{\rho_p d_p^2}\frac{C_D \mathrm{Re}}{24} \\ C_D &= a_1 + \frac{a_2}{\mathrm{Re}} + \frac{a_3}{\mathrm{Re}^2} \\ \mathrm{Re} &= \frac{\rho d_p \left|u_p - u\right|}{\mu} \end{aligned} \tag{5}$$

Where: up is the particle velocity, $F_D(u - u_p)$ is the trailing force per unit mass of particles, u is the water flow rate, g is the acceleration of gravity, ρ_p is the particle density, ρ is the fluid density, F is the other forces, F_D is the damping coefficient, u_p is the particle flow rate, C_D is the trailing coefficient, Re is the relative Reynolds number, d_p is the size of solid-phase particles. For spherical solid-phase particles, a_1 , a_2 and a_3 are constants.

The following assumptions are made in Fluent for discrete phases:

(1)Particle crushing is not considered;

(2)Minor deformations caused by particle-wall collisions are not considered;

(3)The shape of the particles remains unchanged during the collision.

4.3 Calculation of working conditions

Concrete in the inclined shaft chute transportation distance of about 684m, the model distance is long, the number of grids is huge, in order to reduce the amount of calculation, take a section of 3m long U-shaped chute, the section size design as shown in Figure 14, set the slope of the chute for 20 °, 22 °, taking into account part of the chute section slope is too steep, add 25 ° inclined angle of the chute. By changing the inlet velocity and slope of concrete in the chute, in order to simulate the wear of concrete in the chute segments, the design of the calculation conditions as shown in Table 1.

Table 1. The design of the calculation conditions

	serial number	Chute length (m)	Overcurrent depth (mm)	Inlet velocity (m/s)	elevation
One	a	3	120	1.8	20°
	b	3	120	1.8	22°
	c	3	120	1.8	25°
Two	d	3	120	2.5	20°
	e	3	120	2.5	22°
	f	3	120	2.5	25°
Three	g	3	120	3.2	20°
	h	3	120	3.2	22°
	i	3	120	3.2	25°

4.4 Simulation results

The simulation result cloud diagram is shown in Figure 13, which is consistent with the actual picture of the erosion wear occurrence area, and the simulation result is reliable, from the cloud diagram result, the wear mainly occurs in the lower part of the chute, and the wear occurrence location is consistent with the aggregate accumulation area, and the wear serious area is in the vicinity of the central axis, in the case of with the same inlet velocity and different slope.

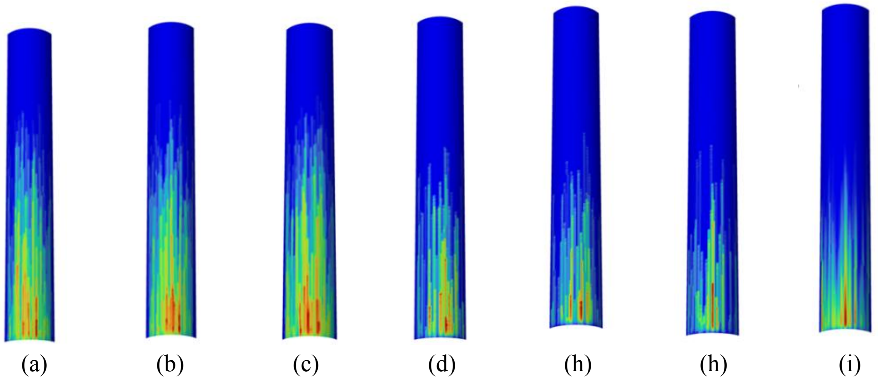

(a) (b) (c) (d) (h) (h) (i)

Fig. 13. Erosion wear cloud

Table 2. Concrete mixing ratios

Cement kg/m³	River sand kg/m³	Stone kg/m³	Water kg/m³	Water reducing agent kg/m³	Water-cement ratio %	Sand content %
370	891	1109	169	0.8	0.45	0.45

5 Aggregate impact wear

Aggregate in the chute down the chute process, are in the slurry package in the movement of the aggregate to provide viscous resistance to prevent concrete segregation, and some surface roughness of the large particles of aggregate requires more slurry package, in order to keep the aggregate can be in the slurry in the smooth flow of aggregate particles, the larger the particles, often need to consume more energy, so the coarse aggregates on the chute of the impact of the most serious wear and tear, razor blade aggregate compared to the light rounded type of aggregates to the Chute damage is greater, as shown in Figure 14 for the collision of coarse aggregate in the chute schematic. In the t0 moment for the aggregate particles and the wall of the encounter, in the t1 time for the aggregate particles penetrate the wall, but the destruction did not stop, when the t2 moment for the particles penetrate the wall, the destruction of the wall to reach the maximum, and the kinetic energy disappears.

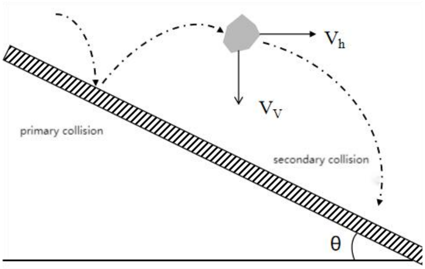


Fig. 14. Aggregate particle collision sketch in chute

Concrete in the chute into the conveyor will be for this period of time was laminar flow movement, with the mortar on the aggregate viscous force of the weakening of the aggregate at this time can be regarded as a vertical direction of the initial velocity of V1, gravity work along the chute to do a uniformly accelerated parabolic motion, accelerated section of the distance of H_L , ignoring the aggregate in this movement during the collision with the wall of the energy loss as well as the horizontal direction of the velocity component, according to the characteristics of its movement can be Determine the following formula:

$$\begin{cases} H_L = V_1 t + \frac{1}{2} g t^2 \\ V_2 = V_1 + g t \end{cases} \tag{6}$$

Where: V_1 is the initial velocity in the vertical direction; V_2 is the speed of the aggregate collision with the wall after acceleration; t is the time taken by the aggregate to collide with the wall in a parabolic motion, and H_L is the height of the aggregate moving in the vertical direction.

A simplification of the above equation yields:

$$V_2 = \sqrt{2gH_L + V_1^2} \tag{7}$$

The above analysis ignores the effect of horizontal velocity on the trajectory of particles, when considering the motion in the horizontal direction, the particles will move farther in the horizontal direction, and at the same time, the height of the particles in the vertical direction will increase, which can be derived from Eq. (7), V_2 is positively correlated with the height, so V_2 will be larger than the arithmetic formula in the actual motion.

According to the momentum principle, as the speed of the aggregate particles increases, its momentum also increases, the speed will be close to zero in a very short period of time when it reaches the wall, and during this time the wall is subjected to a huge impact.[12] During this time, the wall is subjected to a huge impact, and the momentum of the particles is almost fully absorbed by the wall, resulting in a change in the shape of the wall. Assuming that the density of aggregate particles for ρ , the maximum impact velocity for V_2 ,wall shape change in Δt time to complete, then the aggregate particles on the wall of the total mass of the impact is:

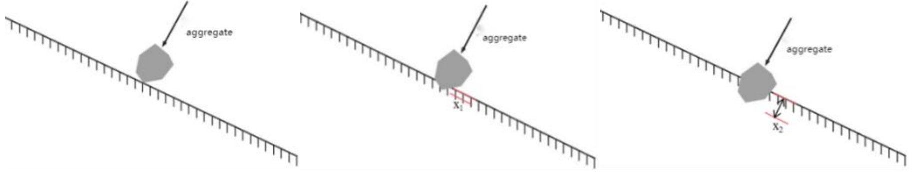
$$\Delta m = \rho V_2 \Delta t S \tag{8}$$

Where: S is the contact area of the particle with the wall.

The impact force on the wall is:

$$F = \frac{\Delta m \cdot V_2}{\Delta t} = \rho V_2 S \tag{9}$$

From the above formula can be seen, the chute wall impact force by the impact velocity and contact area, with the increase of V_2 , the impact force on the wall also increases, with the increase in the surface area of the aggregate, the wall to withstand the impact force is also gradually increased. Therefore, the key to reduce the impact wear of the chute wall is to reduce the impact velocity of particles V_2 or reduce the particle size.



$T=t_0$ $T=t_1$ $T=t_2$

Fig.15. Sketch of particle collision

According to the Hut collision theory[9] , when the coarse aggregate particles collide with the wall, the wall will undergo plastic deformation, assuming that the aggregate is not crushed, the deformation of the wall is expressed as:

$$\Omega=\frac{prd^2v^2}{8H} \tag{10}$$

H is the hardness coefficient of the wall material, d is the particle size of the aggregate particles, the density is ρ , v is the velocity of the particles at the time of impact, and Ω is the amount of deformation of the wall. The particle impact velocity is taken as a constant value and analyzed for different particle diameters. Assuming that the particle acceleration distance is 100m, and ignoring the effect of mortar on particle viscous resistance, the velocity at impact v=17.3m/s, the density of coarse aggregate is set to 1700kg/m³, and the chute hardness coefficient is 40.to Figure **16**

Table 3. Aggregate particle size wear table

Particle size (mm)	10	12	15	18	20	22	25	30
Wear and tear (kg)	0.5	0.72	1.12	1.62	2	2.42	3.12	4.49

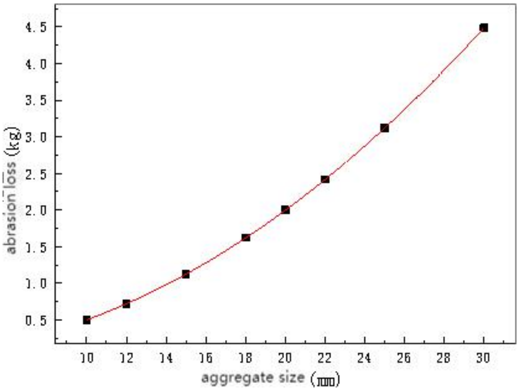


Fig.16. Chute wear vs. aggregate particle size

From Table 3 design ratio, in order to reduce the impact wear of aggregate particles on the chute wall, according to the "Concrete Quality Control Standards", the aggregate particle size is controlled at 10-20mm.

6 Discussion and outlook

CFD-DPM discrete particle method was used for the simulation of erosion wear in the chute, which was corroborated with the pressure distribution of concrete flow in the chute, and the wear at the bottom position of the chute was the most serious, in which when the flow rate of concrete in the chute was low, and the tilt angle of the chute was the smallest, due to the slow flow rate of the concrete as a whole, the particles were easy to settle by the effect of gravity, and the wear of the chute was the most serious in the lower half of the chute.

(1)The maximum wear rate of the chute with an inflow velocity of 1.8m/s and a gradient of 20° is mainly due to the slower gradient, the flow rate is relatively slow, and the aggregate particles are easy to settle to the bottom under the influence of gravity, increasing the number of collisions with the chute wall, and the concrete particles have the most serious erosion and wear of the chute when the gradient is the smallest and the inflow velocity is the lowest, and the wear is gradually reduced with the gradient increase.

(2) When the inlet velocity increases, the velocity of the chute wall wear factor decreases, the chute inclined slope of the chute wear factor increases, the chute slope in the 20 ° to 22 ° shift, the amount of wear decreases, while in the 22 ° to 25 ° shift the amount of wear increases, therefore, in the chute part of the steeper slope areas need to strengthen the protection.

(3) The wear area of concrete in the chute is positively correlated with the amount of wear, in which the wear areas of the first group are all larger than the other groups.

(4) The volume content of aggregate particles in concrete is about 30%, and the simulation of concrete flow in the chute using the DPM particle model has a certain error, and in the subsequent study, a particle flow model that is closer to the real concrete flow can be used to study the abrasion of concrete on the wall.

(5) Subject to the limitations of the experimental conditions, the simulation calculation can only qualitatively analyze the erosion wear, and the real wear there is still a certain degree of error, the follow-up can be explored through the wear experiments on the real wear of concrete on the wall.

7 Optimizing Improvement Programs

7.1 Optimization of concrete aggregates

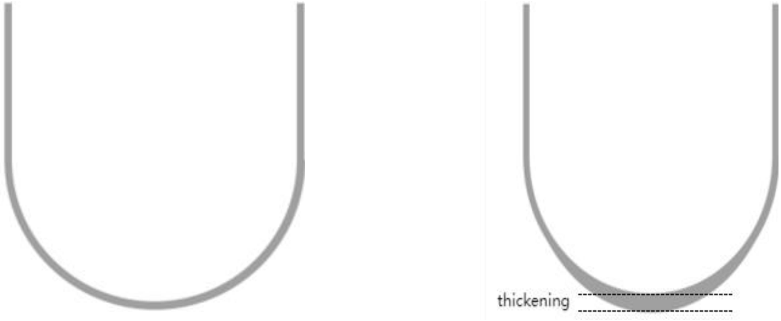
In order to ensure the balance between the fluidity and work ability of concrete, the yield stress and plastic viscosity of concrete can be adjusted from the water-cement ratio, admixture and sand content, cement paste is equivalent to the "lubricant" between the coarse and fine aggregates, the lower the water-cement ratio, the higher the plastic viscosity of the concrete, and the liquidity is stronger, combined with the reality of tunnel engineering, the water-cement ratio should be set at 0.4 ~ 0.45. The yield stress is negatively correlated with the content of water reducing agent, adding a small amount of water reducing agent can improve the fluidity of concrete, but it will also destroy the stability of concrete, for different concrete ratios, the amount of water reducing agent should be controlled. The sand rate is positively correlated with the yield stress, but the high sand rate will reduce the late strength of concrete.

7.2 Chute wall wear optimization

Concrete in the inclined shaft chute long-distance conveying process, the wall thickness is easy to affect the safe delivery of concrete, wall thickness is too thin because of concrete wear and other reasons such as chute leakage, rupture and other safety accidents, the wall is too thick will significantly increase the construction cost of the diversion tunnel, so it is particularly important to determine the reasonable thickness of the chute wall, however, there is no technical standard for the selection of chute conveying thickness, mainly or Engineering experience is the main, taking into account the depth of concrete flow in the chute are d (semi-circular radius) or less, the wall of the chute thickening area is mainly in the semi-circular area.

Concrete flows on uneven material, affected by the friction coefficient of the material, which will lead to the concrete difficult to travel or even flow stop, chute as a carrier for concrete transportation, smooth material is to ensure the stability of the flow of concrete prerequisite. Therefore, it should be selected with solid structure, strong integrality, solid and durable materials to ensure the safety of concrete transportation, chute lap joints at the weld seam is tight without leakage of slurry, and to ensure that the chute lap sequence for the upper section of the chute cover the principle of the lower section of the chute.

Through the simulation analysis in the previous section, the serious parts of the wear occurred in the chute near the central axis, the place for the weakest region of concrete transportation, in order to improve the service life, reduce the number of chute replacement, the chute wall thickening treatment, as shown in Figure 17, the original thickness of the chute is 4mm steel plate, can be the bottom of the chute thickened by 2mm, vertical side of the side wall is not the main area of wear and tear can be appropriately thickened.



(a) Original wall chute (b) Bottom thickening chute

Fig. 17. Chute wall optimization

8 Conclusion

(1) The flow velocity of concrete under different yield stresses and plastic viscosity is simulated by Fluent, with the growth of yield stress or plastic viscosity, the average flow velocity of concrete in the chute will gradually decrease. The wear and tear of concrete on the wall of the chute will gradually increase with the growth of flow rate, and the maximum flow rate of concrete is mainly concentrated in the center of the concrete basin, and the location of the bottom of the chute in the central axis is subject to the greatest pressure, and this location is most seriously eroded by concrete.

(2) Affected by the aggregate particle size and particle shape, the larger the aggregate particle size, the more serious the impact wear on the chute, and in the preparation of concrete should reduce the content of blade-like coarse aggregate.

(3) In order to ensure the transportation quality of concrete and prolong the service life of chute, according to the concrete quality control standards, the proportion of concrete flowing in the chute is optimized, with the water-cement ratio controlled at 0.4~0.45, the sand content controlled within 45-50%, and the particle size of the coarse aggregate controlled at 10mm～20mm.

(4) The CFD-DPM discrete particle method is used to simulate the erosive wear in the chute, the particle inflow velocity and the slope of the chute are also important factors affecting the amount of abrasion, by the influence of the particle settling, the abrasion mainly occurs at the bottom of the chute in the region of the center axis, which is also the main accumulation of particles in the region.

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