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Study on Dry-Method Volume Expansion Technology for Wet Red Mud Yard

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Key words: Red mud yard, Wet method, Dry method, Volume expansion

Abstract: The wet red mud yard in Guizhou Branch of CHALCO is closed when it is used up to 1370m altitude, and it's difficult to construct the new red mud yard within a short term because of the difficulty in land requisition, so, in order to ensure the continuity of alumina production, it's required to expand the volume of the existing wet red mud yard by dry method, so as to extend its service life. Based on tests and studies on the basic performances of red mud filtration cake, the author in this article gives introductions of technologies on red mud dewatering, transportation, spreading out & stacking, reinforcing of weak red mud layer, recycle of waste water in red mud yard, and flood control & drainage etc. It's shown by study achievements that good economical and social & environmental benefits can be obtained by using dry-method volume expansion technology for wet red mud yard.

Foreword

China's aluminum industry has rapidly developed since 2000; in 2009, the output of domestic alumina reached 35 million tons. The capacity of any of six aluminum refineries subordinate to CHALCO has expanded to more than 1 million tons from 20~30 thousand tons within last several years. Private alumina enterprises have boomed with the output accounting for two-thirds of the domestic. As the whole capacity grows fast, red mud discharges increasingly, hence, the exiting red mud yard can't generally meet the expanding requirement. At present, every refinery has started the red mud yard expansion or new construction project, but in either case, due to great increase of red mud, the limit of traditional wet process stock and shortening service life, the land demand is easily exceeding thousands of acres. In view of our densely populated special conditions, economy development, rising land cost as well as the great difficulty of land requisition, land issue is becoming the bottleneck on sustainable development of alumina enterprises.

The alumina capacity of Guizhou Branch of CHALCO reached 0.8 million tons in 2003 as well as 120 million tons in 2007, and the discharge value multiplied. The design elevation for Zhatang red mud yard started in 1987 was estimated to come up to 1355m in 2005. To this end, in the year 2006 wet process heightening project with 1355~1370m was started up to expand to 6.45 million m^3 with the investment of 123 million RMB, extending the service life to the date of July, 2010 which was the ultimate for wet method stock. In 2006, Guizhou Branch invested 499 million RMB in new yard, however, construction process couldn't closely follow the demand of existing yard at site for the reason that land requisition was hindered, which seriously influenced the enterprise's development. In this situation, using dry-method volume expansion instead of wet process disposal is the best and only option to solve red mud follow-up storage for Guizhou Branch.

No successful experience both in domestic and overseas can be referred for dry-method volume expansion operating on wet process red mud yard. New problems, never seen in wet process or dry-method stock, emerged during the implementation process. This subject, began in 2008, incorporated red mud dry-method volume expansion project of Guizhou Branch to carry out this technical research from ten special topics, which filled in the vacancy in red mud disposal technology.

1 Basic performance of red mud filtration cake

Actual ways of red mud disposal in Guizhou Branch are divided into Bayer and sinter; these two methods as well as the method of mixture are researched in this subject as per practical situation.

(1) Chemical composition in red mud

For red mud composition in Guizhou Branch, see Sheet One.

Sheet 1 Main chemical analysis for red mud

Material description	SiO_2	TiO_2	Fe_2O_3	AL_2O_3	CaO	Na_2O	Others
Sinter red mud	21.03	5.02	9.60	11.36	38.00	3.27	11.72
Bayer red mud	13.32	4.43	12.70	21.83	21.09	5.35	21.28
Mixed red mud(1:1)	19.48	4.77	9.76	14.14	33.62	4.31	13.92

In phase composition of sinter and mixed red mud, dicalcium silicate ($2CaO \cdot SiO_2$) content exceeds 50% while it is the main component of cement, therefore, these two kinds of red mud have far stronger mechanical intensity than ordinary tailings after dewatering and consolidation.

(2) Particle grading

In accordance with particle analysis result, silt takes the lead accounting for about 48% in red mud particle of Bayer, while clay making up 28% and sand occupying 28%. Meantime, most of sinter red mud is sand occupying 93%, 7% for silt. In red mud at Bayer and sinter mixing ratio of 1 to 1, the proportion of sand, silt and clay are respectively 50%, 26% and 24%.

(3) Fresh cake mechanical properties

The research group has tested physical mechanical properties on these four-mixing red mud filtration cake: pure Bayer, pure sinter red mud, the mixing ration of 1:1, and Bayer, sinter, ash in the proportion of 50:50:15, please see Sheet Two for result. It is shown that without consolidation fresh cake has comparably high saturation degree with big angle of internal friction, yet cohesion is low.

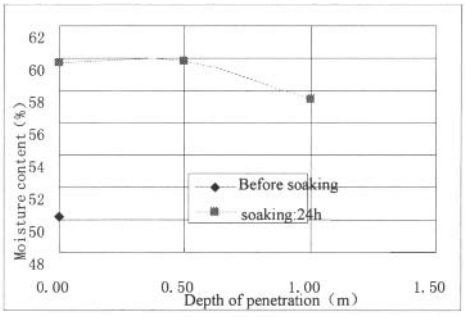
Sheet 2 ***Physical index for fresh red mud cake***

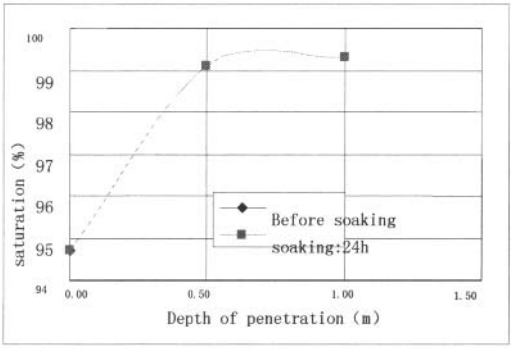
Types of sample	Physical index					Specific gravity of solids	Liquid limit	Plastic limit	Plasticity index	soil consolidation		shear strength (quick shear)	
	soil moisture content	density		void ration	saturation degree					compressibility coefficient	modulus of compression	cohesion	Angle of friction
		wet	dry										
	w	ρ	ρ_d	e	S_r	G_s	w_l	w_p	I_p	a_v	Es	c	Φ
	%	g/cm^3		/	%	/	%	%	/	MPa^{-1}	MPa	kPa	(°)
Pure Bayer red mud	48.4	1.75	1.17	1.35	99.4	2.78	41	24	17	0.21	11.8	8.4	25.7
Pure sinter red mud	53.2	1.80	1.17	1.78	97.7	3.26	44	34	10	0.25	11.0	6.0	34.8
Bayer : sinter=1:1	50.5	1.77	1.17	1.57	97.4	3.03	43	34	9	0.21	12.6	6.5	29.3
50:50:15 Bayer:sinter:ash=50:50:15	49.6	1.76	1.18	1.43	99.5	2.86	47.9	39.0	8.9	0.23	10.6	6.8	28.1

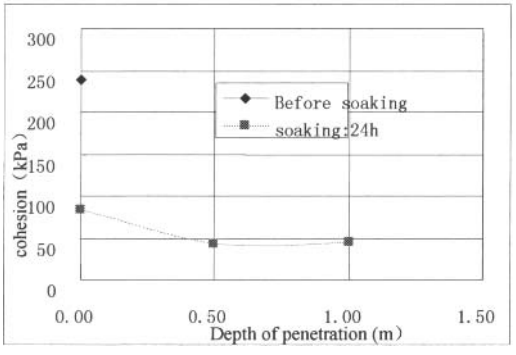
Note: soil moisture content: weight of water is divided by drying solid weight in red mud.

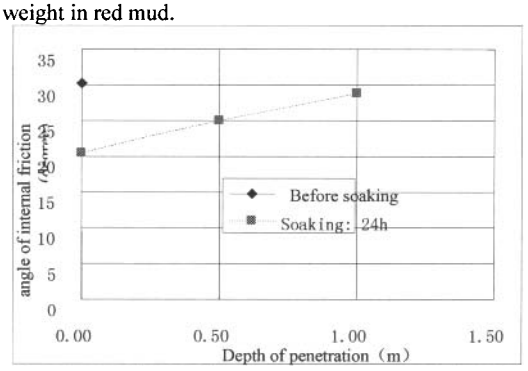
（4）Variation in properties for filtration cake before and after soaking

In order to further test the changes of physical properties of consolidated red mud filtration cake after rain soak, research group carried out test on proportioning red mud at north slope of 3# area of stockpile, change curve of moisture content, saturation degree and shear strength index with penetration depth is shown on the Drawing One.









Drawing 1 Change curve of moisture content, saturation degree and shear strength index

（5）Corrosion measurement

Please refer to Sheet Three for corrosion measurement result. According to the criterion listed in *Solid Waste Corrosion Measurement Glass Electrode* （GB/T15555.12-1995）, pure sinter red mud is corrosive, considered as hazardous waste while red mud of Bayer and the mixture don't have corrosiveness belonging to general solid waste (II Class) .

Sheet 3 ***Corrosion measurement***

Sample type	Ph value of leach liquor	Corrosive judge
Pure Bayer red mud	9.74～9.95	Non-corrosiveness
Pure sinter red mud	12.93～13.34	corrosiveness
Mixing red mud	11.03～11.86	Non-corrosiveness

2 Red mud filtration equipment

The premise is to provide reliable and economical filtration equipments adaptable to various red mud in large-sized alumina enterprises to realize red mud dry-method disposal. It has to be noted that these enterprises should avoid the drawbacks like too many equipments and low automation happening in small refineries.

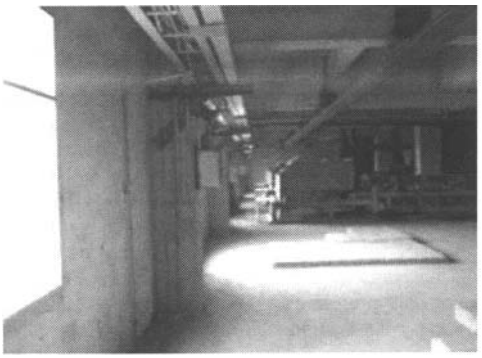
After doing filtration test on types of proportioning red mud with large pressure filter, the result shows Bayer red mud has the best dewatering with the average moisture content of 31.67%, 33.20% for pure sinter and 33.62% for mixing red mud. Meanwhile, good pressure filtration has been proved for types of proportioning red mud.

In recent years, aluminum refineries, adopting filter for red mud

dewatering, normally select filters of large filtering surface, high automation degree as well as stable running, such as Guizhou Refinery, Zunyi Refinery and Shandong Weiqiao Aluminum selecting fast-opening diaphragm pressure filter of 450m^2 which has certain advantages, such as high pressure filtration efficiency, moderate price, short period and steady operation etc.

Although pressure filter is the main equipment of red mud pressure filtration workshop, other matching equipments are required, such as red mud storage tank, filtrate tank, feed pump, filtrate pump, air compressor and belt conveyor etc, which are selected based on pressure filter.

Drawing 2 Pilot red mud pressure filtration workshop in Guizhou Branch



Drawing 2 Large pressure filter on trial

The estimated operating cost for dry red mud is 5.8 RMB per ton.

3 Transporting process of red mud filtration cake

This process is an intermediate link in dry-method disposal. At present, motor transportation for red mud filtration cake is widely used in small refineries in domestic with the characteristics of simple transportation and small capacity.

As to large refineries with dry-method cake storage, there are many difficult issues to solve if transportation is fully dependent on motors. Firstly, more than 200 times per day are required for the heavy trucks of 25t and the refinery with the capacity of 1.2 million tons. Therefore, it requires high degree of road grade, width and gradient, meanwhile motor management & maintenance and fixed personnel are demanding. Secondly, for large storage area which exceeds the operating radius of push-dozer, intensity of foundation soil is highly required so that it is to ensure motors to discharge inside yard. Thirdly, large temporary storage is necessary during the nighttime and rainstorm, after resume of transportation, motors will resume with high energy consumption. Finally, with regards to storage yard in gully type and built near the mountains, it is hard to construct approach roads with the slope less than 6% when the terrain elevation is big; even though on flat ground, there must be certain hidden dangers for motors climbing and encountering on dams at all levels.

In order to seek the safe and reliable scheme to solve the transportation of red mud cake in large refineries, industrial tests on belt conveyor for conveying cake and mobile conveyor were carried out by the research group. The common belt conveyor method used in ore conveying was introduced in the field of red mud cake transportation with certain viscosity and humidity, moreover, it was creative in solving the difficulties such as unloading, anti-viscosity, anti-blockage, slide-proof and shifting etc. to bring about favorable conditions for dry-method disposal and changing wet process yard to dry-method yard.

According to the characteristics of red mud cake (viscosity, alkalinity and humidity, the research group widely investigated various belt conveyor equipments from different manufacturers in dry method test in Guizhou Branch, and had technical exchanges with Chongqing Jingchuan Conveying Machinery Co. Zigong Lifting Conveying Machinery Company, Hebei Lumeika Machinery Company etc. at the site. Finally, TD75 belt conveyor is selected as the main conveying equipment by comparison, which has the advantages of being reasonable in structure, convenient in manufacture and outstanding in economy benefit with the maximum conveying volume of 2996t/h and dip angle of 25°.

Drawing 3 Belt conveyor from pressure filtration workshop

For belt conveyor or mobile belt conveyor, it is fixed at 1200mm or more for belt width and 1.6m/s or above for velocity while the length and arrangement are based on the actual situation.

Transportation cost is 4.54 RMB/ton by motor while 3.43 RMB/ton by belt. By contrast, the transportation technology applied in belt is superior to motor (with high automation), and overall transportation charge in belt convey is lower.

4 Foundation treatment technology in red mud

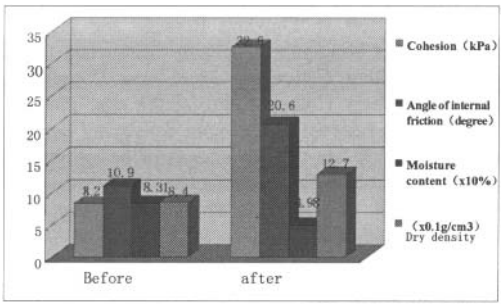
Red mud layer in wet red mud yard is in soft or fluid plasticity state, both of which have the same characteristics of high moisture content, low bearing capacity and large deformation under load. Different from the new dry-method red mud yard on solid foundation, dry-method volume expansion is carried on the existing foundation of wet red mud yard to strengthen the red mud layer, which is essential to guarantee the stability of dry & wet mixed storage.

Referring to the successful experience of foundation treatment technology in the field of domestic geotechnical engineering, the research group analyzes the influence that the process of dry-method volume expansion made on the existing red mud layer. Through the simulated experiment in the lab, the aim is to seek feasible and low cost of wet ground stabilization to define the scope and depth of foundation treatment as well as further obtain the relevant technical parameters.

Taking technology and engineering cost into consideration, it is determined to adopt drainage consolidation method to deal with Bayer red mud foundation according to the actual situation in Guizhou Branch, i.e. high moisture content, high saturation ,30~40m in depth and dozens of hectares of areas.

Through the sand pile drainage consolidation experiment, it aims to observe the changes of moisture content, dry density and shear strength, etc. during the process of drainage consolidation and the elevation of 1390m that red mud gradually accumulated to. Drawing 4 indicates comparison

column chart of main physical index before and after sand pile drainage consolidation.



Drawing 4 Comparison column chart before and after drainage consolidation

From the above drawing, it can be seen that physical properties of Bayer red mud have been obviously improved, moisture content is reduced to the 0.6 times, dry density, internal friction angle and cohesive force are respectively increased to 1.51 times,1.89 times and 3.98 times.

5 The disposal process of filter cake and stacking

The important subject dry-method volume expansion has to face is how to realize the technology of the disposal and stacking from wet to dry method, such as the way of spreading out, drying and rolling compaction after the filtration cake being transported to yard, how to use filtration cake to achieve self-disposal by constructing dam, select operating machines, prevent dust in dry season, guarantee the continuity of alumina production, link up the impervious layer, ensure the stability of accumulated disposal and operating cost etc. Due to the different methods, the past slurry disposal process such as wet and semidry disposal etc. can't solve these issues.

The research group conducts field and test experiments regarding soaking, saturation, drying, rolling compaction, leaching and corrosiveness one by one, and obtained a great quantity of data base about filter cake properties as well as daily operation technology of dry-method disposal and stacking technical parameters.

The economical haul distance for crawler bulldozer is between 50 and 100m. Hence, each zone is divided into several operating unit; filtration cake is transported to unit within one or two by mobile belt conveyor every day, then bulldozer operates. When the laying depth reaches the design requirement, the unit stops piling and enters the drying phase, meanwhile, discharging through mobile belt conveyor shifts to next unit. As industrial moisture content in drying unit is reduced to 27.5%~29.6% (i.e. the best soil moisture content: 38%~42%). The next step is to compact red mud by compacting press, when the required dry density index is achieved, the work flow in this unit is finished, and then the next round starts.

The compaction degree for dam and its foundation should be more than 95% when filling; for the compaction of non-dam red mud within the scope of most risky slip circle is above 90%. There is no requirement for other sections, only with its own gravity to consolidate.

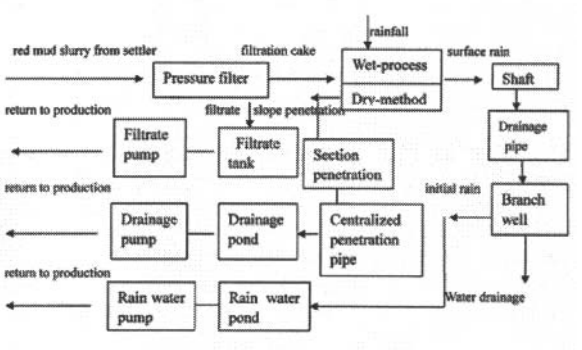
The operating cost after the dry-method volume expansion mainly consists of machinery depreciation, oil consumption as well as operating personnel salaries. The total cost for red mud is estimated at 4.9 RMB/t.

6 Waste water recycle

Water is the carrier for red mud transported from plant to disposal, the same for red mud attached alkali. The influence on environment is reflected in the pollution caused by seepage of red mud water content Moreover, several domestic dam failure had something to do with the rising phreatic line led by poor permeation.

The effective way to reduce the pollution is to set impermeable facilities at the foundation and side slope, but it is equally important to decrease red mud water content and install waste water recycling facilities so as to improve the rate of wastewater reuse. In addition, it will accelerate the consolidation of red mud to enhance the yard safety. Therefore, the effective waste water recycling facilities is both for safety need and environmental requirement, the far-reaching significance lies in be consistent with national policy of energy saving and emission reduction.

After dry-method, there are three kinds of alkali waste water to recycle: filtrate from pressure filter, slope surface seepage on the wet disposal, early-stage rainfall with alkali being washed on the surface of dry red mud. Combined with characteristic of dry & wet coexisting method, it is to adopt percolation and filter pressing for recycling water in red mud, meanwhile, drainage system is used to recycle early rainfall. For this reason, it will not only protect water, but also save process water and reduce alkali consumption.



Drawing 5 Process flow of waste water recycle

After dry-method volume expansion, returning water rate is increased from 61% to 94%, returning water volume is added up to 2.885 from 1.88 million tons per year, on the contrary, water consumption volume is reduced to 190 thousand tons from 119.5 million tons, the saving volume of production water with akali is 100.5 million tons per year and the alkali is reduced by 4.525 thousand tons.

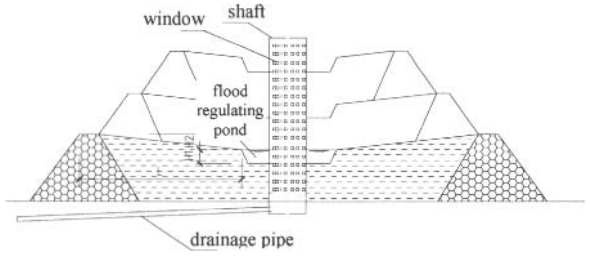
7 New type technology of flood control & drainage

When wet red mud yard is converted to dry-method disposal, the moisture content, mode of distributing and stacking greatly change, too. Correspondingly, drainage system couldn't simply continue to follow the way used in wet process yard. New type drainage should be researched to meet the relevant requirements of safety and environmental protection, smoothly connect with the former drainage facilities. In the meantime, it needs to achieve the target of cost saving and expand the volume to the great extent.

After analyzing the existing drainage technology of red mud yard, the research group comes up with the new type drainage system applicable to the dry-method volume expansion on wet yard based on the process change and filtration cake characteristics, that is to set drainage shaft at the center of

disposal and reserve a regulating pond with a certain height and reservoir capacity around the shaft with the purpose of flood control. The holes or frames reserved on well are used in absorbing water, and then water is discharge out of disposal through pipes within72hours.

Drawing 6 indicates the new structure of drainage.



Drawing 6 Drainage structure applied in dry-method volume expansion

This structure overcomes the shortcomings of the available technology and defines the flood controlling area into the small area, which subsequently prolong the length of dry distributing. When disposal is in progressive rise, the time of dry distributing reducing to the minimum length will be extended; the height and land volume will be greater than the disposal with the conventional drainage system. Hence, more red mud can be stocked in the certain storage area, which will save the cost of newly constructed disposal and occupation, finally obtain better economic and social benefits.

8 Technical economy analysis

For the scheme of follow –up disposal after piling up wet yard, there are three options to select: new construction wet yard, new construction dry-method yard as well as changing wet to dry method yard. Each of these has its advantages and disadvantages.

To construct new wet yard, it is necessary to expropriate the land, install the facilities used for transportation, distribution, seepage-proofing, drainage, back water, early stack and so on. The investment is high, operating cost is low, yet water consumption is great with the low efficiency of storage capacity and high risk of seepage.

If it is planned to construct dry-method yard, it is the same to set up the above mentioned facilities. However, the engineering quantity of early stack is small with the lower investment, operating cost is a little greater while water consumption is low with the great efficiency of storage capacity and little risky seepage.

For the method of changing wet to dry-method yard, it is required to acquire a small amount of land to build pressure filtration workshop, filtration cake transportation, drainage and early stack, etc. The existing facilities for seepage-proofing and back water can be resumed. This method is provided with the characteristics of new dry-method yard but less investment.

The main basis of business decision making is technical economy analysis. Due to the different capacities, production process, red mud properties and geological conditions etc. the economic indicators of red mud disposal are not the same. However, unit capacity investment, joint disposal cost of red mud per ton and red mud disposal per unit area are universal, which are regarded as the main indicators to evaluate the rationality of disposal scheme.

Taking Guizhou Branch of CHALCO as an example, a tech-economic analysis is made on volume expansion for wet process red mud disposal. The height of the disposal is increased from the existing 1330m--1370m (wet process) up to 1390m for dry method application. With 300220 thousand RMB investment cost for additional 18425 km^3 capacity, it is possible to extend the usage time for additional 15.4 years. The unit investment cost is calculated as 16.4 RMB/m^3 in addition to 15.3 RMB/ton for transportation. Comparing with the scheduled new red mud disposal by Guizhou Branch, approximate 199630 thousand RMB can be saved from the capital investment in addition to 24.9 RMB/ton from the transportation.

Judging from the volume rate on each unit land, domestic large red mud disposals take between 6.4～55.6m^3/m^2 with average of 22.3 m^3/m^2. While the same for dry method disposal on the existing volume expansion in Guizhou Branch could be increased from 26.6m^3/m^2 up to 48.7 m^3/m^2, about 118% higher than domestic average.

From the cost-performance ratio, as the investment on the land requisition, environment and safety facilities have be tremendously increased since 2000, the unit land volume investment is of 6.7～58.6 RMB /m^3 with 24.9 RM/m^3 in average while the same from the existing disposal volume expansion for dry method is of 16.3RMB/m^3, which takes 65% that of the domestic large wet mud disposal. The economic efficiency is very remarkable.

The advantages through dry-method volume expansion on the original wet process assure the continuity of the production, fully utilize the land so as to tremendously reduce the land occupation, limit the pollution sources to the environment, increase the safety factor of the disposal and shorten the rehabilitation time.

9 Conclusion

Red mud disposal is part of alumina production process. A new red mud disposal takes hundreds acre of land and hundred millions of RMB capital investment. This research achievement and the successful experience obtained from the existing red mud disposal volume increment for dry method application can be a good solution for different alumina refineries to solve the difficult problems after the existing wet red mud disposal is full, and also provide reliable basis and abundant experience for design, construction and management of existing wet red mud disposal to be converted into dry red mud disposal application after volume expansion, and create a benefit condition to assure the continuation of the existing alumina refinery enterprises and consequently solve the problems of long period construction duration, huge investment cost and expensive management cost due to land requisition. The result benefits the land secondary usage and the environment protection.

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