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Effect of Slag Fineness on the Strength of Cemented Backfill

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ABSTRACT

Jiuquan slag(JQS)is a kind of acid low activity slag. In order to stimulate its potential activity and solve its problem of low strength, the original slag powder(OSP) produced by Xijin Company is pulverized for 1.0 hour(1h) and 1.5hours(1.5h) to obtain different fineness of the slag powder, And then through its particle size and microscopic analysis to explore the impact of slag fineness on the strength of cemented backfill(SCB). The results show that as the grinding time increases, the particle size of slag decreases rapidly, After 1.5h grinding,the average particle size of the slag powder decreases from 24.31μm to 12.26μm and decreases by 49.6%;The microscopic analysis shows that the mechanical grinding is mainly on the particle size and surface morphology of slag have an impact, will not change its internal crystal structure and phase composition; the unconfined compression strength(UCS) of cemented backfill increases with the increase of slag fineness, Compared with the OSP, the UCS of 3days(3-d) and 7days(7-d) of the medium-sized slag powder(MSP) after grinding for 1.0h increased by 33.3% and 30% respectively, and the UCS of 3-d and 7-d of the superfine slag powder(SSP) after grinding for 1.5h increased by 63% and 53.6% respectively.

KEYWORDS: slag powder; fineness; activity; cementitious material; strength

INTRODUCTION

Slag is a kind of material with vitreous body as the main component and has hydraulic activity,which formed by the high temperature slag discharged from pig iron smelting process after water quenching [1-2]. The statistical results show that China's iron and steel enterprises blast furnace ironmaking slag annual emissions amounted to more than 50 million tons, but the recycling rate only about 83%,which not only occupy a large amount of waste slag land, but also a serious environmental pollution [3-4]. How to make full use of slag and make it become a treasure is a major issue facing China's resource-saving and comprehensive utilization.

Jinchuan nickel ore is China's largest, the world's third largest copper sulfide nickel sulfide deposits. The ore deposit is characterized by deep (buried depth), thick (ore body thick), broken (ore broken), high (high stress) and is known in the mining industry, which belongs to the large and difficult mining deposits at home and abroad. The drift fill stoping mining method was adopt, which means the more complex mining process and higher cost. In recent years, the global mining economy is in a downturn. High cost filling mining makes the enterprise face enormous economic pressure. Reducing the filling cost is the key technical problems of Jinchuan nickel mine to solve. Therefore, this paper explores the impact of slag fineness on the SCB. Based on this, the early-strength filling cementitious material is developed with the acid slag powder of Jiuquan as the main raw material, Providing technical support for the comprehensive utilization of low cost and high efficiency filling in Jinchuan mine[5-15].

THE PHYSICOCHEMICAL ANALY OF THE JQS

The main chemical components and quality indexes of the JQS are shown in Table 1. It can be seen that the average value of the activity coefficient(M_n) of the JQS is 0.29 (less than 0.3),so the JQS belongs to the low-activity pozzolanic material, Meanwhile the average value of alkaline coefficient(M_O) of the JQS is 0.9(less than 1.0), so it belongs to acidic slag; the average value of quality coefficient(K) of the JQS is 1.44(less than 1.6) , it also belongs to the low-activity slag, but achieves the available slag activity requirements.

Table 1: Chemical composition and quality index of the JQS

Composition	SiO_2 /%	Al_2O_3 /%	Fe_2O_3 /%	CaO /%	MgO /%	MnO /%	TiO_2 /%	M_n	M_O	K
Content	38.34	12.3	0.63	37.95	7.82	0.48	1.40	0.29	0.90	1.44

PARTICLE SIZE ANALYSIS OF THE JQS POWDER WITH DIFFERENT FINENESS

Xijin Company pulverizes the JQS to produce slag powder by using high-energy ball mill. In order to analyze the hydration reaction of the slag powder with different fineness, Through the grinding of the OSP produced by XiJin company at different times, we can get slag powder with different fineness, and then carry out particle size analysis and microscopic observation.

In order to analyze the particle size of the slag powder with different fineness, the MSP and the SSP was obtained by grinding the OSP separately for 1.0h and 1.5h by ND6-4L ball mill. The results of the particle size analysis are shown in Figure 1 and Figure 2, It is the particle size distribution curve of different particle size of slag. And then the particle size distribution characteristics of the slag powder with different grinding time are obtained,they are shown in Table 2,it Includes characteristic particle size(d_{10}, d_{30}, d_{60}, d_{av}), nonuniformity coefficient(C_u), curvature coefficient(Cc), particle size distribution characteristic value(D_e) and uniform coefficient(n).

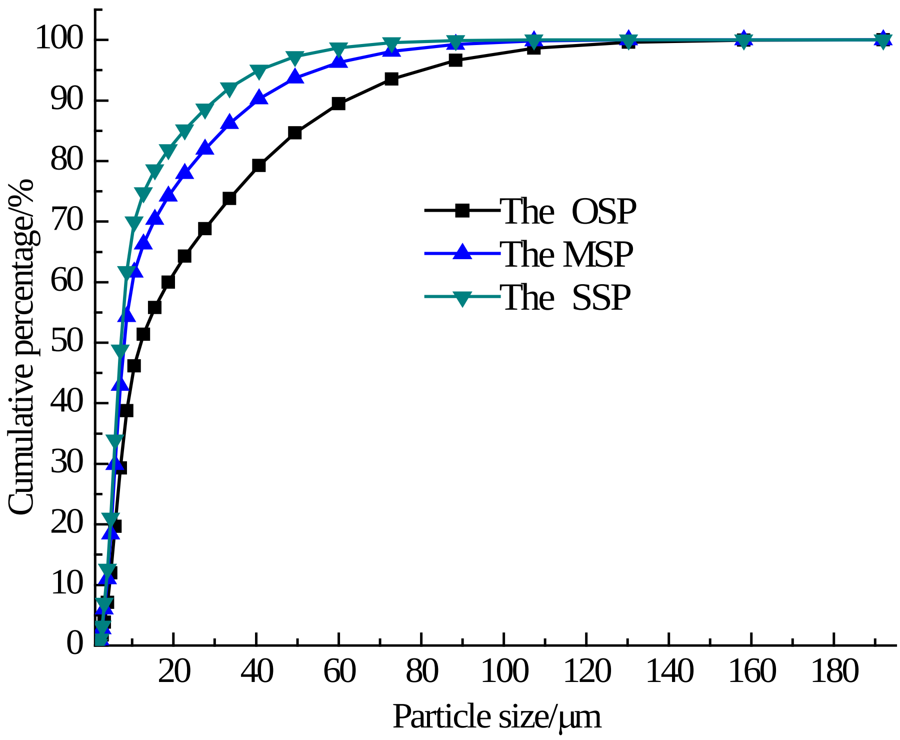


Figure.1: Cumulative distribution curve of slag powder particle size with different fineness

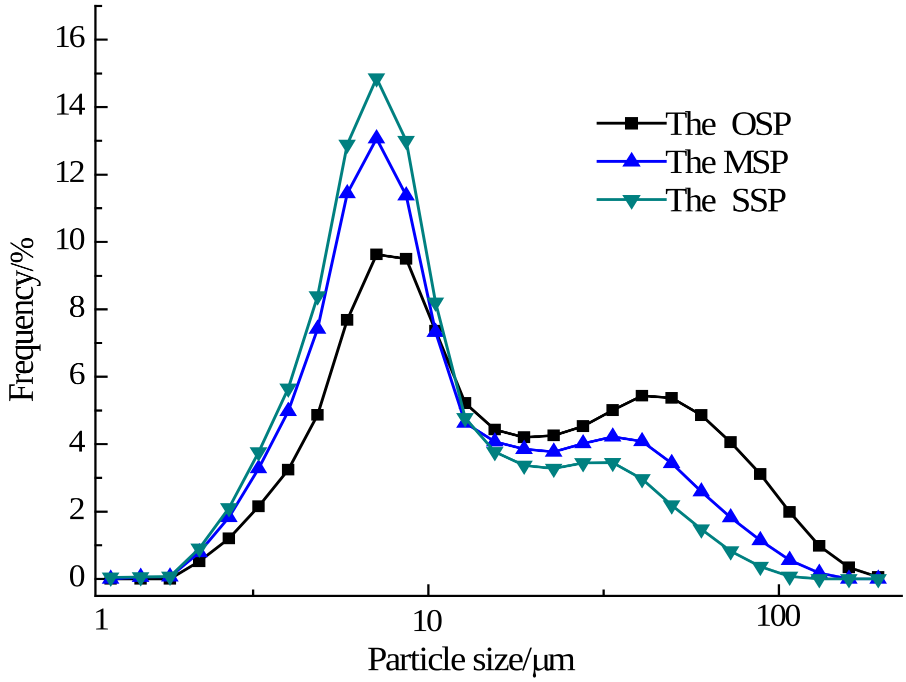


Figure 2: Frequency distribution curve of slag powder particle size with different fineness

According to the results of slag particle size analysis and table 2,we can see that with the increase of grinding time, the mechanical smashing and grinding caused the particle size of slag to decrease rapidly. The average particle size of slag after 1.5h grinding decreased from 24.31μm to 12.26μm, decreasing by 49.6%,which indicates that the slag powder gradually entered the dynamic equilibrium stage of crushing, refining and coarsening in the process of grinding,Meanwhile with the increase of grinding time, the size distribution of slag powder becomes narrower gradually. The value of n in Table 2 is uniformity coefficient,it reflects the width of the particle size distribution, The value of n is the larger, the particle size distribution of the slag powder is the narrower and the value of n is the smaller, the particle size distribution is the wider. It can be seen that the n value increases with the increasing of grinding time. It shows that the particle size distribution of the slag powder is narrower and narrower, that is, the large particles are gradually reduced and the particle size is more and more concentrated, mainly concentrated in the 3~15μm. The figure 2 shows that the tine of the OSP is grinded is the longer, its particle size frequency curve is the steeper.

Table 2: Characteristics of particle size distribution of slag powder with different fineness

Category	d_{10}/μm	d_{30}/μm	d_{60}/μm	d_{av}/μm	C_u	C_c	De/μm	n
The OSP	4.05	8.14	20.63	24.31	5.09	0.79	22.49	1.015
The MSP	3.72	6.10	12.88	15.88	3.46	0.78	13.80	1.263
The SSP	3.56	5.61	10.05	12.26	2.82	0.88	10.61	1.617

MICEOANALYSIS OF THE JQS

XRD and SEM were used to test the change of particle structure and particle morphology of slag in different grinding time. The results of XRD analysis of the slag powder with different fineness are shown in Figure 3, it can be seen that the slag powder is basically in the amorphous state and contains a large number of vitreous phases. It is known from the atlas that the XRD Atlas of the slag powder has not changed obviously after grinding,which indicates that the crystal structure and phase composition of slag powder will not change due to mechanical milling. That is to say, mechanical grinding mainly affects the particle size and surface morphology of slag particles.

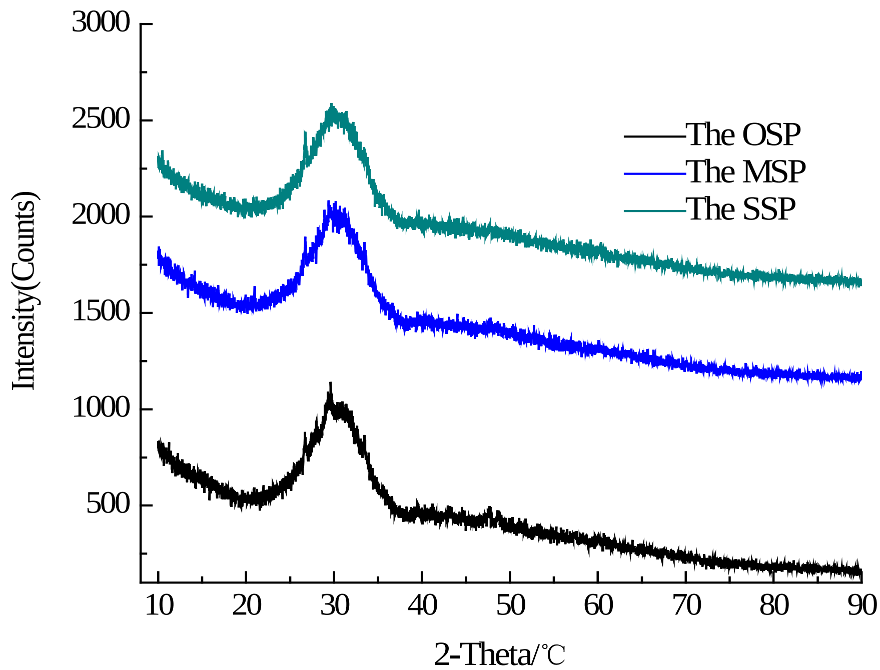
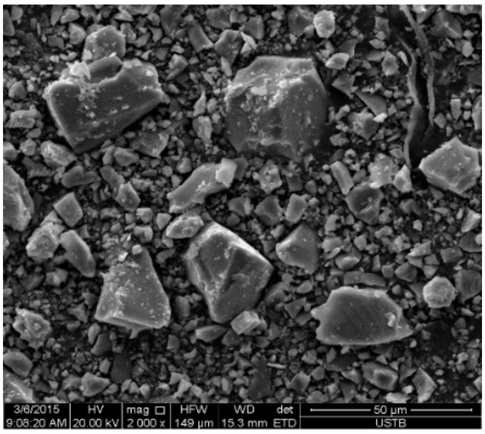
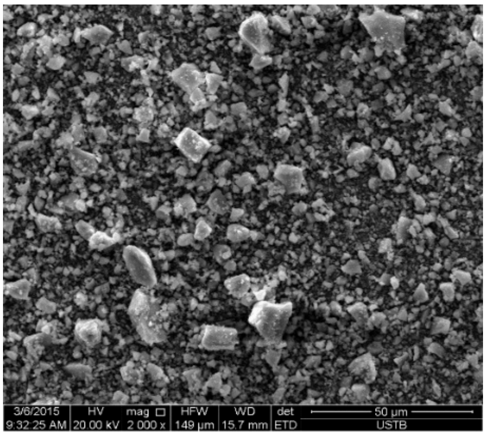


Figure 3: XRD Atlas of slag powder with different fineness

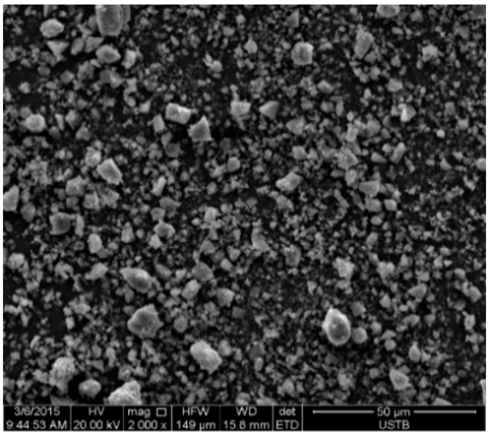
The scanning electron microscope diagram of the surface morphology of the the powder with different fineness is shown in Figure 4, It can be seen that the OSP mainly consists of irregular polygons massive particles, and the diameter of the particles vary, the largest particle diameter of about 25μm; After grinding 1.0h, the irregular massive particles were broken up further. Most of them changed into pebble-shaped particles. Only a small number of large particles were found, and the diameter of the particles was obviously thinning, the particle size was smaller, the edges and corners of particles became less, and the roundness increased; After grinding 1.5h, the slag powder particles are completely transformed into pebble-shaped particles. There are basically no irregular granular particles, which are regular small particles, and the surface is relatively smooth.



（a）The OSP



（b）The MSP



（c）The SSP

Figure 4: Surface topography of slag powder with different fineness

STRENGTH OF CEMENTED BACKFILL WITH DIFFERENT FINENESS SLAG POWDER

Experimental design and results

The strength test of cemented backfill of new cementitious material (NCM)was carried out according to the slag powder of different fineness. The test design cement sand ratio is 1:4, the slurry concentration is 80%, the filling aggregate is less than 20mm river sand coarse aggregate. The test results of 3d and 7d strength of the cemented cemented filling materials developed by three different fineness slag powders are shown in table 3~ table 5.

Table 3: Orthogonal test results of cemented backfill strength of the NCM developed by using the OSP

Number	Calces /%	Desulfurization ash /%	Flyash /%	Mirabilite /%	Na_2SO_3 /%	OSP /%	Strength /MPa		Shrink rate /%	
							3d	7d	3d	7d
A1	4	17	18	2.0	2.0	57	0.75	2.17	7.02	9.36
A2	4	17.5	19	2.5	2.0	55	0.74	1.67	7.25	7.18
A3	4	18	20	3.0	2.0	53	0.81	1.94	8.26	8.26
A4	4.5	17	19	3.0	2.0	54.5	0.79	1.53	7.41	7.13
A5	4.5	17.5	20	2.0	2.0	54	0.64	1.69	7.25	7.35
A6	4.5	18	18	2.5	2.0	55	0.65	1.55	6.41	7.58
A7	5	17	20	2.5	2.0	53.5	0.68	1.42	6.70	6.58
A8	5	17.5	18	3.0	2.0	54.5	0.75	1.61	7.07	7.21
A9	5	18	19	2.0	2.0	54	0.61	1.41	6.66	6.51
Mean	4.5	17.5	19	2.5	2.0	54.5	0.71	1.67	7.11	7.46
A0	Mine filling cement(MFC)						1.29	1.85	7.62	7.41

Table 4: Orthogonal test results of cemented backfill strength of the NCM developed by using the MSP

Number	Calces /%	Desulfurization ash /%	Flyash /%	Mirabilite /%	Na_2SO_3 /%	MSP /%	Strength /MPa		Shrink rate/%	
							3d	7d	3d	7d
B1	4	17	18	2.0	2.0	57	1.08	1.99	6.9	6.6
B2	4	17.5	19	2.5	2.0	55	1.07	1.66	4.2	6.1
B3	4	18	20	3.0	2.0	53	0.89	1.68	4.5	5.8
B4	4.5	17	19	3.0	2.0	54.5	0.97	1.63	5.3	3.3
B5	4.5	17.5	20	2.0	2.0	54	1.01	1.38	5.8	4.1
B6	4.5	18	18	2.5	2.0	55	0.95	1.68	3.8	4.3
B7	5	17	20	2.5	2.0	53.5	1.01	1.54	7.9	6.1
B8	5	17.5	18	3.0	2.0	54.5	0.88	1.61	5.5	4.7
B9	5	18	19	2.0	2.0	54	0.94	1.44	4.9	4.1
Mean	4.5	17.5	19	2.5	2.0	54.5	0.98	1.62	5.42	5.01
B0	**MFC**						1.51	2.78	6.5	8.5

Table 5: Orthogonal test results of cemented backfill strength of the NCM developed by using the SSP

Number	Calces /%	Desulfurization ash /%	Flyash /%	Mirabilite /%	Na_2SO_3 /%	SSP /%	Strength /MPa		Shrink rate /%	
							3d	7d	3d	7d
C1	4	17	18	2.0	2.0	57	1.32	2.20	8.33	4.81
C2	4	17.5	19	2.5	2.0	55	1.20	1.96	8.67	7.54
C3	4	18	20	3.0	2.0	53	0.95	2.14	4.50	7.43
C4	4.5	17	19	3.0	2.0	54.5	1.16	2.35	7.51	9.86
C5	4.5	17.5	20	2.0	2.0	54	1.00	1.89	5.90	8.76
C6	4.5	18	18	2.5	2.0	55	1.00	1.66	4.89	3.66
C7	5	17	20	2.5	2.0	53.5	1.00	1.58	6.70	5.93
C8	5	17.5	18	3.0	2.0	54.5	1.00	1.83	5.99	4.48
C9	5	18	19	2.0	2.0	54	1.27	1.81	5.54	4.42
Mean	4.5	17.5	19	2.5	2.0	54.5	1.10	1.94	6.45	6.32
C0			**MFC**				1.74	3.67	6.03	5.63

Analysis of test results

The strength test results of the NCM is developed by slag powder with different fineness are showed in. table 6. Figure 5 shows the relationship between the strength of cemented backfill and the average particle size of different fineness slag powder. Thus it can be seen that improving the fineness of slag powder can significantly increase the strength of the cemented backfill of the NCM. From Figure 5, it is found that when the average particle size of slag powder decreases from 25μm to 16μm, the strength of 3d and 7d of cemented backfill increases linearly, and the growth rate of 7d intensity is greater than that of 3d. However, when the average particle size of slag powder decreases from 16μm to 12μm, the intensities of 3d and 7d of cemented backfill show an exponential rate increase. In comparison, the 3d strength growth rate of ultrafine slag powder is obviously higher than that of 7d. It shows that ultrafine slag powder with a mean particle size of less than 15μm can significantly improve the early strength of the cemented backfill, especially the strength of 3d.

Table 6: Strength test results of the cemented backfill of the NCM developed by different fineness slag powder and the MFC

Fineness	Mean particle size/μm	NCM				Mean strength /MPa			
		3d		7d		NCM		MFC	
		Test value /MPa	Increase rate /%	Test value /MPa	Increase rate /%	3d	7d	3d	7d
OSP	24.31	0.81	0	1.53	0	0.81	1.53		
MSP	15.88	1.08	33.3	1.99	30.0	1.08	1.99	1.51	2.77
SSP	12.26	1.32	63.0	2.35	53.6	1.32	2.35		
Mean	17.48	1.07	48.1	2.09	41.8	1.07	2.09		

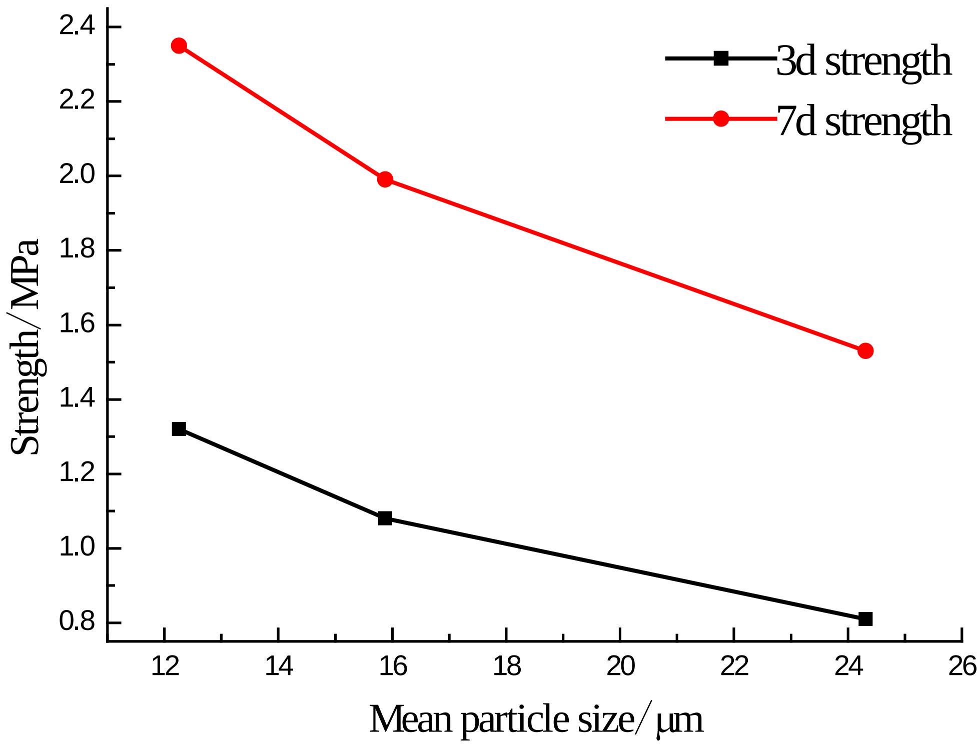


Figure 5: The relationship between the strength of the cemented backfill of the NCM and the mean particle size of the slag powder

CONCLUSION

(1) According to the physicochemical analysis of the JQS,the average activity coefficient (Mn)is 0.29, and its alkaline coefficient(M_0) is 0.90, Therefore, the JQS is a low active acid slag.

(2) Through the microscopic analysis, the XRD Atlas shows that mechanical grinding mainly affects the particle size and surface morphology of the slag particles, and does not

change the crystal structure and the phase composition of the slag particles.

(3) Under the same conditions, the strength of cemented backfill increases with the increase of slag fineness. The 3d and 7d strength of the MSP increases by 33.3% and 30% respectively compared with the OSP;The 3d and 7d strength of the SSP increased by 63% and 53.6% respectively compared with the OSP, and the improvement effect was more significant.

(4) According to the results of the strength test of the NCM, the 3d and 7d strengths of the filled cementitious materials based on the SSP is respectively 1.32MPa and 2.35MPa, which is 87% and 85% of the strength of the cement cemented backfill.

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