

Prevention and Control of Mud-Rock Flow in Mine Waste Dump

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Abstract: This paper describes in details the formation conditions and characteristics of mud-rock flow in mine waste dump and gives hazard evaluation on the mine mud-rock flow with full and accurate data investigated from typical mud-rock flows once occurred in the waste dumps of Dexing copper mine. It presents also means and methods for detailed analyzing and forecasting mud-rock flow in the waste dump by analogy procedure as well as methods for calculating scope, scale and waste rock loss of mud-rock flow occurring in the mine waste dump. Finally the paper proposes various kinds of methods and engineering measures for prevention and control of the mud-rock flow in mine waste dump so as to minimize its hazard and adverse effect.

Keywords: waste dump, mud-rock flow, prevention and control

Introduction

Our country has a large population, but is relatively short in water and soil and always hit by serious soil erosion. With rapid development of our national economic construction, the man-made loss of water and soil is increasingly serious due to sever deforestation, dumping refuse and soil in disorder and ignorance in water and soil conservation during project development and construction. Therefore, it is necessary to understand from a view of strategy that the water and soil conservation is essential for improvement of the national land and rivers, is the foundation for the national economic and social development and is a national policy that must be adhered for a long period of time in our country. To place the water and soil conservation on the agenda, including enhancing knowledge of the water and soil conservation and strengthening prevention and control of the loss of water and soil, is an important task facing to us.

To study the mud-rock flow in waste dump is a new subject that has been given much attention by governments and departments at various levels and already a special subject about the environmental protection and water and soil conservation. The author is intended to give personal experience from his practice in this regard for reference by the people in the same occupation.

1 Formation conditions and characteristics of mud-rock flow in waste dump

1.1 Formation conditions of mud-rock flow in waste dump

A vast amount waste rock and soil is produced in the course of the mankind's development, construction and production, such as opening mines, stripping waste rock and building plants, railway and highway, etc. The dumping location and pattern of these waste rock and soil as well as local weather and other factors would lead to a mud-rock flow, which can be called the mud-rock flow in waste dump. Same as the one occurring in the natural world, this kind of mud-rock flow would endanger the lives and properties of the mankind in the same way.

Like the mud-rock flow occurring in the natural world, the mud-rock flow in waste dump cannot occur without the following essential elements:

- (1) Steep hill slope and valley that is easy to collect water;
- (2) Recharge of abundant loose and fragmental rock and soil;
- (3) Heavy raining or large catch-water run-off.

For occurring of the mud-rock flow, not a single one of the above-mentioned three elements can be dispensed with.

1.2 Investigation and case analysis on mud-rock flow in waste dump

According to the investigation and records of relevant data, several serious mud-rock flows have occurred in Dexing Copper Mine since its establishment.

(1) Before construction of the Nanshan open pit in Dexing copper mine, nearly 240,000 m³ of earth and stone were dumped along the northeast hillslope of the temporary access road during its construction. Later on, most of another 200,000m³ earth and stone were dumped on the earth slope at outer side of the access road. After the rainstorm in summer of 1967, a large amount of soil and stone rushed down the hillslope and filled the Dawuhe stream, thus forming a mud-rock flow that burst the road bridges and culverts and blocked the river course and culverts; as a result, a 5km- long course of Dawuhe stream downward from the mine was silted and river bed went up by 0.1m—0.2m. In spring of 1968, the dredging of Dawuhe stream course gave about 80,000m³ of silt.

(2) After the coyote blast of Niulongshan Mountain for opening the Nanshan open pit, several hundred thousand cubic meters of waste rock were dumped at the hillside around Nanshan mountain, and a great quantity of waste rock was accumulated in the temporary waste dump located at hillslope of the southwest side of the pit. After the rainstorm in summer of 1970, a serious mud-rock flow occurred in this waste dump; it rushed into the Dawuhe stream through branch valleys and dredging of Dawuhe stream had to be conducted in 1970 and 1972 respectively.

(3) By the end of 1983, 37.57 million tons of waste rock was already accumulated in Yangtaogou waste dump with a slope elevation difference of over 100m and a large berm area at the crest whose surface inclined outward. In 1983, the surface run-off water all flowed toward the outer edge of the slope due to the rainstorm, thus a gulch was formed on the slope of the waste dump. The largest gulch was about 20m—30m wide and about 10m deep, and 10,000m³ waste rushed down through the gulch and silted the valley by 600m long at toe of the slope, as a result, the valley bed went up by 1m—2m.

1.3 Characteristics of mud-rock flow in waste dump

The investigation and analysis show that the mud-rock flow in waste dump is generally caused by man-made activities, so its characteristics are different from the natural mud-rock flow.

(1) Possible to forecast: It is possible to forecast the its time, place, nature, rough scale as well as regions to be endangered and range to be impacted.

(2) Centralized: As the recharge of sold materials will be usually concentrated on one or few fixed places, generally, the mud-rock flow will not become widespread.

(3) Short duration: The mud-rock flow will mostly occur during waste dumping, especially at beginning of waste dumping. When the waste dumping is stopped or the waste dump is in trend of becoming stable, the mud-rock flow activity in the waste dump will subside or stop gradually.

(4) Variation by steps: The mud-rock flow scale will change from large to small, its frequency will change from more to less and its property will change from viscous to diluted and identical to a water flow finally, which vary generally with properties and conditions of mine rock and soil.

(5) Preventable: The mud-rock flow in waste dump can be prevented according to rainstorm intensity and quantity of run-off.

2 Hazard from mud-rock flow in waste dump

Once a mud-rock flow occurs in waste dump, it will seriously endanger lives and properties of people, which mainly include the followings:

(1) Blocking river course, heightening river bed, weakening preventative capability of river embankment and endangering lives and properties along banks of the rivers;

(2) Submerging farmland, silting agricultural irrigation channels, reducing storage capacity of water reservoir and damaging industrial and agricultural water conservancy facilities;

- (3) Blocking bridges, culverts and threatening safety of railway and highway subgrades and bridges;
- (4) Eroding waste dump and causing adverse effect on the safety and stability of the waste dump;
- (5) Polluting rivers, destroying water sources and causing adverse effect on the utilization of water resources.

Hazard cases about mud-rock flow in waste dump

(1) The Shanqian waste dump of Hainan iron mine had accumulated about 28.76 million tons of waste rock from 1959 to 1979; the mud-rock flows occurred within this period of 20 years had submerged as more as 32hm² of rivers and farmland, created about 2,520,000m³ silt in total; its thickness reached 6m—12m and rising speed of river bed was 1.1m/a on average. The weathered soil in the mud-rock flow amounted to 70%—80% of the total waste rock.

(2) A great quantity of waste rock from Yunfu troilite mine in Guangdong Province was dumped into Datai and Dongan these two waste dumps located at upstream of Datai channel and Dongan channel. By 1983, totally, about 20 million cubic meters of waste rock were dumped into these two waste dumps. Because plenty of water caught from Dajinshan area flowed into Dongan channel all year round along the valley from the south to the north, many gulches formed on the slope of the waste dumps, then plenty of waste rock and sandy soil flowed with water into the channel, thus forming a mud-rock flow. According to the investigation by Guangdong Environmental Protection Institute in 1982 and 1983, the total silted mud and sand within the area of water reservoir reached about 11.41 million tons since building of the dam in Datai reservoir (located at downstream of Datai waste dump), taking up about 22.85% of the Datai reservoir capacity.

3 Prevention and control of mud-rock flow in waste dump

It is necessary to carry out the policy of “putting prevention first, and combining prevention with control” in mud-rock flow control. That means it is necessary to try to avoid or avoid by taking engineering measure the possibility of mud-rock flow in waste dump when selecting site location. In case a mud-rock flow occurs, it is necessary to minimize the hazard and adverse effect from the mud-rock flow.

To prevent and control the mud-rock flow, it means to take artificial control measures in the waste dump once the mud-rock flow occurred so as to restrict re-appearance of the mud-rock flow and reduce the mud-rock flow frequency, scale and harmfulness.

3.1 It is possible to forecast mud-rock flow in waste dump

Regarding occurrence of mud-rock flow, not a single one of above-mentioned three essential elements can be dispensed with. That means the mud-rock flow will never occur with shortage of anyone of the three essential elements. However, the steep and easy-to-catch water slope and broken terrain exist popularly in every mountainous waste dump; recharge of abundant loose and fragmental rock and soil is possible in every waste dump; heavy raining or run-off of water collected may happen in vast areas of both the southern and northern parts of our country, the only difference is that the raining in the southern part is heavy and may last for a long time, so, large-scale mud-rock flow that may endanger large area may occur frequently; while in the northern part of our country, though annual raining is rare, yet it appears mostly as rainstorm concentrated in July, August and September; the rainfall in the northern part in summer that may last for a short time but may be heavy will easily become a run-off due to sparse surface vegetation and no enough time for seeping into the ground, then this run-off will wash and erode the waste dump, thus the mud-rock flow may easily occur in the waste dump.

When we know clearly about reasons for occurrence of the mud-rock flow and its developing course in the waste dump, it is possible, in the engineering design, to forecast and calculate the mud-rock flow that may occur according to the geological, hydrological and weather data collected from the place where the project is located so as to take preventive measures in the engineering design.

In 1985, ENFI carried out analogical analysis and forecast on mud-rock flow in several waste dumps like Zhujia, Huangkeng and Xiyugou in Dexing copper mine. The following table indicates the main data from the investigation and measurement in that very year.

Waste Dump	Zhujia	Huangkeng	Xiyuangou	Remarks
Watershed area (km ²)	5.1	3.4	1.5	
Landform	Horseshoe valley	Steep valley	Steep valley	
Height above sea-level	125—350	100—400	125—400	
Natural slope	Gentle, about 7%	Steeper, about 14%	Steeper, about 14%	
Distance from water divide to valley mouth (km)	3.30	2.20	2.90	
Distance from the dump to residential district or important projects (km)	1.30	1.00	0.8	
Planned volume of waste rock accumulated (t)	721,570	367,190	32,000	
Accumulating area (km ²)	3.5	1.8	0.8—1.5	
Bench height at outermost slope of waste dump (m)	125	200	175	
Lost slope of waste rock (%)	12.8 8.3	18.2 14.3	19.0 12.5	Highest dump Initial dump
Distance of waste rock washed away (m)	1,600	3,900	3,600	Measured slope: 7.7%
Lost modulus of waste rock predicted: Annual average modulus (m ³ /(km ² • a)) Annual max. modulus (m ³ /(km ² • a))	2,757 4,642	2,757 4,642	2,757 4,642	All are data measured in Yangtaowu waste dump
Comparative factor for prediction	2.5	2.0	1.2	1.0
Loss of waste rock predicted: Annual average (m ³) Annual max. (m ³)	35,151 59,185	18,747 31,565	4,962 8,355	7,702
Downstream range affected by mud-rock flow				

It can be easily seen from above table that mud-rock flow in all waste dumps would cause a certain impact on the mines and the influence area will be quite different depending upon the preventive measures.

In case no preventive and control measures are taken at initial period: As the waste rock has the inclusion, like surface overburden and weathered rock and soil, in the initial period, heavy loss of waste rock, large influence area and long distance of mud-rock flow will crop up; till later period, as the overburden and weathered rock and soil have reduced, the mud-rock flow will almost become a water-rock flow, as a result, both extent and area of influence will be reduced accordingly.

In case preventive measures are taken during engineering design: A rock-retaining dam is provided in the design for retaining most of lost waste rock. This is an effective measure for prevention and control of the mud-rock flow in mines over the years; or a flood conditioning and impounding reservoir is designed at the downstream for storing acidic water and silt from the waste dump so as to facilitate settlement of the silt in the flood and decrease of harmfulness from the mud-rock flow.

3.2 Influence area of mud-rock flow forecast by analogy procedure

3.2.1 Selecting analogy factors

The relevant data and parameters measured in Yangtaowu waste dump are selected as the analogy factors. The area measured at exposed slope (eroded plane) of the waste dump and designed data are selected for comparative analysis. Then the analogy calculation is conducted by supposing that the comparative factor of Yangtaowu waste dump is 1.0, that of Zhujia waste dump is 2.5, that of Huangkeng waste dump is 2.0 and that of Xiyuangou waste dump is 1.2.

3.2.2 Forecasting influence area of mud-rock flow

For forecasting the influence area of the mud-rock flow, the calculation is made based on the section measured at Yangtaowu waste dump and supposing that the slope of waste rock silted in the valley bed in Yangtaowu is 7.7% on average over the years. The lost distance of waste rock is related to the height of the waste dump, so the initial dump height is considered; till the later period, the waste dump slope is in a trend of becoming stable. In addition, after formation of dumping bench, even waste rock may lose from the upper part, most of the waste rock will stay on the bench, so loss of waste rock outward the bench will be reduced considerably.

3.2.3 Forecasting loss of waste rock

For forecasting loss of waste rock, the erosion modulus of Yangtaowu waste dump is taken as the base, which is multiplied by the analogy factors and watershed areas of various waste dumps. Because the waste rock loss will decrease progressively as time goes on, it is estimated according to experience after measurement that the waste rock loss will be tending towards stop about 10—15 years later.

3.3 Prevention of the mud-rock flow

For prevention of the mud-rock flow in waste dump, firstly, it is necessary to minimize possibility of the mud-rock flow, then if a mud-rock flow already occurs in a waste dump, it is necessary to bring it under control.

3.3.1 Selecting a proper waste dump location, which is of the first importance in preventing mud-rock flow in waste dump

To select a proper waste dump location is not merely an economic consideration, but it is also a safety consideration, and even more it is related to the water and soil conservation, a basic policy of the country. If a reasonable and proper location is selected for the waste dump, the mud-rock flow will not easily happen, then the preventive and control measures will be more simple and easy. On the contrary, more expense in preventive measures, hard control, heavy loss of water and soil and serious damage to industry, agriculture and safety of people's life and property nearby would be the results. Taking Huangkeng waste dump as an example, though it was close to North Mountain where low transportation cost would be needed, yet it was only 1.0km from the residential district that would be affected by the waste rock flow because of high terrain clearance of the waste dump, so it was decided to abandon this waste dump location during the design.

3.3.2 Improving waste dumping method to prevent mud-rock flow

It is advisable to take advantages of narrow valley mouth and wide hinterland of the valley, i.e. to dump waste rock first to the valley mouth to form a dam there, then to dump the waste rock from the outer to the inner, thus creating a procedure for dumping the waste rock from top to bottom and in many benches. This is right the improvement of the dumping method proceeding from the consideration of reasonable accumulating location and safety dump height and is helpful in preventing the mud-rock flow

in the waste dump. Of course, this damming-type waste dumping method will not depend upon a single factor but will depend upon comprehensive factors, such as location and elevation of the mine and waste dump. Regarding Yangtaowu waste dump in Dexing copper mine, the river valley at upstream was already cut off in 1984 and all surface run-off water seeps through the bottom of the waste dump, thus eliminating gravity erosion to the waste dump and reducing or avoiding the mud-rock flow.

3.3.3 Draining surface rainwater of the waste dump so as to prevent formation of the mud-rock flow

To drain the surface rainwater of the waste dump is though simple, yet people concerned do not often attach much attention to it. As it can exert a considerable influence on stability of the waste dump slope, managerial people at various levels and technical people should attach great importance to this matter. Generally, the waste dump top should slope inward so as to avoid formation of run-off at the top of the waste dump; otherwise, washing and eroding the waste dump top and slope could lead to a mud-rock flow.

3.3.4 Strengthening waste dump management so as to prevent mud-rock flow

Regarding mud-rock flow prevention measures, besides the necessary engineering measures, there should be necessary management measures, i.e. it is necessary to strengthen the management over the waste dump. The mine should incorporate the waste dump management into its daily production management in order to prevent the mud-rock flow. It is necessary for the mine to set up special department for strengthening the management over the waste dump and monitoring station for monitoring and inspecting the waste dump so as to accumulate the data and prevent the mud-rock flow, all these will be of great significance and play great role in production and construction. At present, many mines in our country have set up special organs for engaging specially in the management and monitoring of the waste dumps, which have played positive role in preventing the mud-rock flow.

4 Control of mud-rock flow in waste dump

For controlling the mud-rock flow in waste dump, China has already gained considerable experience, including mainly engineering measures for tackling this problem by comprehensive way.

4.1 In place where mud-rock flow may occur

(1) It is possible to build a flood retaining dam in a proper place of waste dump upstream according to the topographic features for retaining the upstream flood or run-off and diverting them from the waste dump so as to avoid direct washout to the waste dump and prevent the mud-rock flow.

(2) According to properties of rock and soil dumped or by taking some appropriate measures, it is possible to plant grasses and trees in large area of waste dump top and slope; or grouting and solidification measures can be taken in the section where the mud-rock flow may easily occur in the waste dump so as to cut off recharge source of solid materials and prevent the mud-rock flow.

(3) It is also possible to build a permeable rock-fill dike dam with chunk rock in the valley at slope toe of the waste dump so as to prevent the mud-rock flow.

4.2 In place where mud-rock flow may pass through

The following appropriate works can be implemented in the area where mud-rock flow may pass through so as to divert or retain the mud-rock flow, then harmfulness from the mud-rock flow can be alleviated.

(1) Building grid dam

It is possible to build a gravity dam with concrete, reinforced concrete or cement-stabilized rubble in the valley; steel grids are installed in the overflow part of the dam to retain big rock or boulder in the mud-rock flow and let remaining mud and water flow through so as to reduce harmfulness from the mud-rock flow.

(2) Establishing diverting channel

A mud-rock flow diverting channel can be established at middle or lower reach of waste dump in loess area, where mud-rock flow may easily occur, so as to prevent silting of the mud-rock flow, covering of valley bed and river shoal as well as washout of both banks of the valley bed where the mud-rock flow passes through, then the hazard from the mud-rock flow can be reduced. The diverting channel provided in Hainan iron mine for diverting Shanqian “diluted” mud-rock flow has given a tangible result in reducing damage to “Shilu-Basuo railway” by the mud-rock flow.

(3) Establishing buffering pond or mud storage pond

A buffering pond or mud storage pond can be established in a proper place of the middle or lower reach where the mud-rock flow may pass through so as to make the mud-rock flow slow down and settle in the pond, then clear water in the pond will flow out from the diverting port so as to control range and extent of hazard from the mud-rock flow. This method has been used for controlling the Shanqian mud-rock flow in Wushiling valley of Yunfu triolite mine, Guangdong Province, and the results sound good. The acidic water conditioning reservoir built at the lower reach of the waste dump in Dexing copper mine is used to settle part of silt rushed down from the waste dump, then the satisfactory results in alleviating hazard from the mud-rock flow have also been achieved.

4.3 In mud-rock flow accumulation area

A silt retaining site may be provided in a proper downstream section of the waste dump, where mud-rock flow may easily occur. It is used for retaining and impounding the mud-rock flow thereby reducing silt-retention area and extent of hazard from the mud-rock flow. This method has been adopted by Hainan iron mine and No. 2 Mine of Jinchuan Non-ferrous Metals Corporation in their mining design, where good results have been achieved.

5 Conclusions

Both positive prevention and strengthening of control are necessary in dealing with the mud-rock flow in waste dump. By doing so it is possible to reduce effectively the frequency, hazard extent and influence range of the mud-rock flow in the waste dump. Though the mud-rock flow is unavoidable in the mine waste dump, as long as much attention is given to investigating its regularity, it is possible to control it step by step and minimize its hazard and influence.

References

- [1] Beijing Central Engineering and Research Institute for Non-ferrous Metallurgical Industries, “Environment Impact Assessment Report on Mud-rock Flow in Waste Dump for Phase III Project of Dexing Copper Mine”, November 1985.
- [2] Liu Bangxiang, Tong Shuquan, Ding Qihua, Mao Aiming, *et al.*, Beijing Central Engineering and Research Institute for Non-ferrous Metallurgical Industries, “Investigation on Mud-rock Flow in Hainan Iron Mine and Yunfu Triolite Mine”, May 1984.