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## Study on Soil and Water Loss Characteristic of the Railway Construction in Mountain Area

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**Abstract :** The factor of human project activity is often the immediate cause resulting in soil and water loss. The Baoji-Lanzhou second railway in construction is an example. The soil and water loss law caused by earth and stone mountain railway engineering construction in the northwestern China is studied systematically and that caused possibly by the road bed project, the road moat project, the field project, the tunnel project and the service road project in construction is probed. At the same time, the type, the intensity and influencing factor of soil and water loss in the northwestern mountain railway construction are also studied.

**Key words :** Mountain railway ; Soil and water loss ; Characteristic.

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### 1 Summary

Soil and water loss is not only a serious problem existing generally in the world, but also an increasing one in China. The human factor is often the immediate cause resulted in soil and water loss. In certain meaning we can think that soil and water loss is the evil consequence in that people have gone against nature law and destroyed the ecological environment, and haven't put the land and other natural resources to rational use. It is estimated that the soil erosion amount in the prehistoric whole world is only  $9.3 \times 10^{10}$  t. Since the human being is engaged in the cultivation widely, the soil erosion amount has increased by 2 ~ 3 times now. But otherness in different areas is relatively great. Our country has a large population and has high demands of grain and civil fuel, etc. In a situation that the productivity level is not high, it makes people put undue emphasis on grain yield and ignore adapting synthetical development of agriculture, forestry and livestock farming to local condition but to rob land to cultivate and open up the land suited to forestry and animal hus-

bandry as farmland. The abrupt slope is cultivated so much that it becomes more and more poorer. In this way the ecosystem will be in vicious circle. Such actions as cutting about and denuding the forest, and even digging the tree root, lawn make the trees fall sharply and uncover the ground surface, which all have aggravated soil and water loss. In addition, some capital construction does not meet the water and soil conservation request. For example, building the highway, founding the factory, digging the coal and quarry unreasonably will destroy the vegetation and make the slope stability reduce to generate more serious geological calamity as landslide, cave-in, mud and stone flow.

### 2 Characteristic of fetched and discarded soil in railway construction

The railway project constructs mainly with machinery, manpower secondarily. The types of major project are: road bed and field project; bridges

and culverts project; tunnel project.

The roadbed limit slope and the topographic features of the area lead to heavy filling and digging amount of cubic metre of earth and stone. The roadbed project beyond the bridges and tunnels is basically either digging or filling. The discarded residue of tunnels is a part of the project of cubic and metre of earth and stone, and its amount is heavy. The discarded stones have large particle diameters. The lengthways utilization must be done well. We may move the dug soil to excavate and make full use of the discarded residue of tunnels to reduce the floor area of the fetched soil and the discarded residue so as to reduce effectively soil and water loss caused by the project of cubic and metre of earth and stone.

### 3 Present status of soil and water loss along the Baoji-Lanzhou Railway

#### 3.1 Types and distribution of soil and water loss

The types of soil and water loss along the Baoji-Lanzhou railway are mainly hydraulic erosion and mass erosion. Soil erosion appears in such forms as surface erosion, ditch erosion, landslide, landslip, mud and stone flow. The surface erosion: Scale surface erosion and rill surface erosion are included mainly. It often exists on the sloping surfaces with none or little vegetation along the line. The ditch erosion: The ditch erosion strengthens gradually from shallow ditches to cutting ditches, then to gulleys. It is more serious in the area where the ground surface is short of grass and woods and people and animals have frequent activity. The landslide: It once happened in the river valley of Wei River. It mainly relates to human activity. The landslip: Generally it happens in the range of 70 ~ 90 degree of slope. The mud and stone flow: It is a kind of mixed erosion. Under the combined actions of hydraulic power and gravity, a large amount of unconsolidated formation on the ground surface slip into channels and form mud and stone flow.

#### 3.2 Genetic analysis of soil and water loss

Soil and water loss mostly forms under the synthetic actions of natural factor and human factor. Natural factor is the objective potential condition which causes soil and water loss. Human factor is the main factor of

accelerating and preventing soil and water loss.

#### 3.2.1 Natural factor

Natural factor mainly includes climate, land form and topographical features, ground material composition and vegetation etc.

##### (1) Climate.

Climate effect on soil erosion mainly represents precipitation direct erosion. Although yearly precipitation is not heavy in the area along the railway, because the storm rainfall has fast, violent, strong, short characteristics, and at the same time if the vegetation on the ground surface is bad, cut-off ability is low, so that precipitation haven't enough time to ooze but converge into radial flow and carry the clastic matters on the ground surface into ditch and stream channels. The storm rainfall is the main dynamic condition causing the radial flow erosion. According to the materials of the meteorological department, precipitation in summer and autumn accounts for 70% ~80% of that in whole year along the line, and the rainfall distribution in every year are uneven. The maldistribution of the time of the precipitation and heavy rainfall intensity in rainy season is one of the main reasons causing soil and water loss. The rainfall general situation in the urban districts passed through along the line is shown in chart 1.

(2) Land form and topographical features and ground material composition.

The Loess Plateau has wavy terrain and broken topography. At the same time, it has valleys vertically and horizontally, steep slope and long ditch. All these are main topographical factors causing soil and water loss. Under the general situation: The slope has positive correlation with the flow velocity and erosion amount. The more steeper the slope is and the more it produces, the faster the flow velocity is and the bigger the soil erosion is. The longer the slope is and the heavier the converged flow is, the faster the flow velocity is and the stronger the agent of erosion is. Soil types along the line are mainly yellow soft soil, secondly brown earth, gray earth, black soil and brunisolic soil. The soil of these types has deep accumulation and large porosity, and has vertical joint development. Soil particles are thick and soil structure is loose. And it has low content of clay particles and humus, and high

lime contentso that it is easy to scatter and to be taken away by surface runoff to form soil and water loss.

Table 1 The rainfall general situation in the urban districts passed through along the Baoji-Lanzhou second railway

| County<br>(district)             | historical average<br>(mm) | precipitation percentage of<br>July, August and September | The most day precipi-<br>tation (mm) | The most precipitation<br>in 10 minutes (mm) |
|----------------------------------|----------------------------|---|--------------------------------------|--|
| Jintai district                  | 696.6                      | 62.5  | 169.7                                | 22.5   |
| Baoji county                     | 700                        | 60  | 76.8                                 | 13.6   |
| Beidao district of Tianshui city | 504.2                      | 75  | /                                    | /  |
| Gangu county                     | 467.4                      | 54  | /                                    | /  |
| Wushan county                    | 477.5                      | 87  | 77.46                                | 19.9   |
| Longxi county                    | 445.8                      | 65  | /                                    | /  |
| Dingxi county                    | 425.1                      | 69  | /                                    | /  |
| Yusheng county                   | 328                        | 56  | 96.8                                 | /  |
| Chengguan district               | 328                        | 61.9  | 96.8                                 | /  |

### 3.2.2 Human factor

The human factor is also the important reason of soil and water loss in project district. It is shown in three aspects:

(1) The forest is cut excessively and woodland reduces so as to lose water self-restraint ability. Most areas originally along the line have dense forest, green hills and clear waters. But now because of excess cutting, many fires in history and long-term chaos caused by wars, it makes the forest area reduce greatly. In addition, some areas are engaged in sideline occupation and have excess cutting. So it makes soil lose the primary condition of water self-restraint ability to cause soil and water loss.

(2) Capital construction has neglected water and soil conservation, and strengthened river sediment. In the past water-and-soil conservation measures were not considered basically along the line of the railway, when these areas built the highways, made mines, factories, and hydraulic engineering, etc. A large amount of abandoned soil, broken stones, slag pile up on the hills randomly or dump into stream channels to increase the sediment runoff and reduce flood control ability of the rivers. As a result, the flood overflows the bank to make tablelands become waste rock patch. Affected by capital construction, the area of the naked original rock expands constantly.

(3) The abrupt slope is opened up. The forest and grassland are destroyed to be cultivated. All those and the influence of the natural calamity make vegetation resources destroyed constantly and make vegetation on the hillside reduce. In consequence, soil and water

loss is aggravated and the ecological environment worsens increasingly.

### 3.3 Present analysis and assessment of soil and water loss

Because of the influence of the human factor and natural factor, soil and water loss of different degrees exists in Shanxi Province and Gansu Province along the line. According to departmental erosion modulus and project land use along the line, the estimated present soil and water loss value in the range of possessive land is  $7 \times 10^4$  t/a.

Research shows:

Under the combined actions of natural factor (climate, topographical features, vegetation, etc.) and human factor, there is soil and water loss of different degrees in the areas along the line of the railway. The type of soil and water loss is mainly water erosion. From the analysis of erosion modulus, the degree of soil and water loss in Jintai district of Baoji city is the lightest, and Beidao district and Longxi county are more heavier.

According to specific environmental quality and the degree of soil and water loss, the department concerned in the counties (districts) along the line of the railway has taken different prophylactic-therapeutic measures of soil and water loss. It mainly includes: returning land for farming to forestry, forestation and growing grasses and comprehensive administration taking minor watershed as a unit. It has already made some achievement and results, but there are still such questions existing as just considering the moment benefit ignoring long-term interest and having no effective

measures to prevent soil and water loss caused by people.

The government of every county (district) along the line has made corresponding soil and water conservation program and pointed out the developing direction and prophylactic-therapeutic measures.

The floor area of the Baoji-Lanzhou second railway is  $1266.49 \text{ km}^2$  (including temporary ground area of  $374.97 \text{ km}^2$ ). In this range the estimated yearly amount of soil and water loss is  $7 \times 10^4 \text{ t/a}$ .

#### 4 Working capacity of fetched and discarded soil in railway construction

It is indicated that amount of discarded soil and residue produced in the construction of the project is shown as follows:

(1) Amount of the fetched and discarded soil produced in roadbed project

Because the Baoji-Lanzhou second railway goes in the canyon bench with high mountain and steep slope, and the tunnels and bridges are joint, it is very difficult to allocate the cubic metre of earth and stone. This time the cubage of excavation of the road moat is  $471.43 \times 10^4 \text{ m}^3$  and the remaining is  $304.77 \times 10^4 \text{ m}^3$ , which is discarded in appointed soil field. Roadbed project makes most use of the cubage of excavation of the road moat and tunnel discarded residue, and still needs fetched soil. In our design the way of the centralized fetched soil is adopted. The total roadbed fetched soil amount of the whole line is  $304.76 \times 10^4 \text{ m}^3$ .

(2) Amount of discarded soil and residue produced in tunnel project

The tunnel mucking this time is  $473.42 \times 10^4 \text{ m}^3$ . The utilized mucking is  $29.41 \times 10^4 \text{ m}^3$ , and the discarded is  $444.01 \times 10^4 \text{ m}^3$ . The canyon sector where the tunnel lies has steep mountain. The river is crooked and the river valley is narrow. In addition, the amount of the discarded residue of the tunnel is heavy. So it is difficult to discard the residue. If the chosen place and prevention of the discarded residue are improper, the Sand-carrying capacity of the rivers along the line will increase and the partial bed river will rise to flood the farm land on the ground.

(3) Amount of discarded soil and residue pro-

duced in field project

The field project makes full use of the excavated soil and still needs fetched soil of  $440.3 \times 10^4 \text{ m}^3$ , which is fetched in centralized field. The discarded soil of  $215.7 \times 10^4 \text{ m}^3$  is discarded in appointed soil field.

In the construction period of the Baoji-Lanzhou second railway, the total amount of the discarded soil and residue produced is  $964.48 \times 10^4 \text{ m}^3$ , and the fetched cubage of excavation is  $745.06 \times 10^4 \text{ m}^3$ . Among them, the discarded cubage of excavation is separately  $268.05 \times 10^4 \text{ m}^3$  in Shanxi province and  $696.43 \times 10^4 \text{ m}^3$  in Gansu province. The fetched cubage of excavation is separately  $218.97 \times 10^4 \text{ m}^3$  in Shanxi province and  $526.09 \times 10^4 \text{ m}^3$  in Gansu province.

If these discarded soil and the fetched soil field don't adopt the corresponding prevention, the discarded soil will become the material sources of soil and water loss in rainy season, and the fetched soil field will reduce the ability against erosion because of the destructive vegetation and the loose soil layer on the ground surface. The immediate raindrop erosion will aggravate soil and water loss and have a great influence on the ecological environment.

#### 5 Forecast of soil and water loss in the construction

Soil runoff equation U-SIR of the United States Department of Agriculture is adopted combined with relevant test achievements and actual investigation along the line.

Amount of soil and water loss caused possibly by the cross section of the road bed and the road moat

The total length of the roadbed project of the Baoji-Lanzhou second railway is  $279.9 \text{ km}$ . The occupied land of the roadbed body project is permanent land use. It is  $16 \text{ m}$  wide on average. This time it is predicted that the average occupied land width beyond the shoulder of road is  $6.5 \text{ m}$ , the embankment slope is  $1$

$1.5$  and the road moat slope is  $1:0.75$ . According to the historical rainfall materials, the soil condition and the roadbed body project situation of every county, it is predicted that the estimated erosion amount of the roadbed project is  $37662 \text{ t/a}$  without any water-and-

soil conservation and protective measures among two-year construction period, which adopts pattern calculation combined with the research achievement of the local Water Conservation Department and actual investigation.

Amount of soil and water loss caused possibly by fetched and discarded soil field of the roadbed project and the field project

The fetched and discarded soil field of this roadbed and field project mostly distributes on the dry land and wasteland of two sides of the railway. The total fetched soil amount of the whole line is  $745.06 \times 10^4 \text{ m}^3$ , and the discarded amount is  $520.47 \times 10^4 \text{ m}^3$ . In this process the slope change is relatively heavy. If the average slope is considered as 30% combined with the research achievement of the local Water Conservation Department and actual investigation, the erosion amount of the pattern calculation is 46 943 t/a among two-year construction period.

Amount of soil and water loss caused possibly by the station and living quarters

This time the field project needs to be extended. The newly-increased permanent land use and the railway purchased land is  $140.19 \text{ hm}^2$ . Because the field project has the characteristic of centralized occupied land and slow slope, the erosion amount among two-year construction period is  $140.19 \text{ hm}^2$ .

Forecast of soil and water loss caused possibly by the discarded soil (residue) of tunnel

The occupied land of the discarded residue of the total tunnel concentrates in Baoji county and Beidao district mainly. The land use of the tunnel project is mainly for the discarded residue and part jamb. The majority are dry land, irrigated land and wasteland. The ones that aggravated soil and water loss are mainly the discarded field. According to the characteristic of the railway project and the rainfall condition of the counties along the line, the erosion amount of every discarded field among two-year construction period is 15 174 t/a without any water-and-soil conservation and protective measures among two-year construction period. The produced amount of soil and water loss of this project among the construction period is  $10.52 \times 10^4 \text{ t/a}$ . The amount of Shaanxi Province is  $1.79 \times 10^4 \text{ t/a}$

and that of Gansu Province is  $8.73 \times 10^4 \text{ t/a}$ . The produced amount of soil and water loss is more on grade surface of the road bed and the road mat, the fetched and discarded soil field of the roadbed project and the discarded residue field of the tunnel.

Forecast of soil and water loss caused possibly by the access road of construction

Main arterial highway is 5.5 m wide and 183.2 km long. The newly built is 100.7 km long among them. The rebuilt existent access road is 82.5 km. The main arterial highway: When highway goes along the railway line, the highway is used as the main arterial highway of the railway material transportation. The building of the main arterial highway without available highway in this project divides into three kinds of situations. The main arterial highway is generally used as the permanent road. The sector of no local highway along the railway and the road that the existent railway has already formed (in the boundary of the railway land) will rebuild in this project. For the round sector of the newly-built second railway, the main arterial highway is rebuilt in the boundary of newly-increased railway land in this project. The local highway entering the main arterial highways of the railway and newly-built second railway needs to be built to introduce the main arterial highway, which generally need to take over the permanent land for use.

The rebuilt main arterial highway generally carries on simple making level and rolling of the existent road surface. There is not cubic metre of earth and stone projects basically. The built main arterial highways and the introducing one that utilize rural road have a small amount of cubic metre of earth and stone projects. Surplus discarded soil and residue is thrown away to the discarded soil and residue field that the railway project plans to build in construction. Drainage ditch is set up on both sides of the road. The newly-built main arterial highways and the introducing one have relatively heavy cubic metre of earth and stone. Surplus discarded soil and residue is thrown away to the discarded soil and residue field that the railway project plans to build in construction. The main arterial highway is used forever for the railway maintenance and local traffic. After the project is completed, it is guaranteed that road surface

is even and the road is expedite.

The introducing access road is 3.5 m wide and 223.8 km long. The newly-built is 89.5 km long. The rebuilt existent access road is 134.3 km. The introducing access road is generally used as the temporary use of the railway construction and the land is used as the temporary land of the railway. According to local need, the access road is partly introduced and used as local permanent road. After construction the introducing access road is block up. The introducing access road is divided into the following two kinds of situations. One part of it needs to be newly built and the other part needs to be rebuilt. It includes the built road that enters fabricating yard, and that used for the fetched and discarded soil field of the roadbed and field project and the discarded residue of the tunnel.

The built introducing access road that utilizes local rural road only needs simple making level and rolling, and the cubic metre of earth and stone project is relatively small. The majority of the newly-built introducing access road are built for the fetched and discarded soil field and the discarded residue field. The part of the road land is dry ditch and wasteland. When the newly-built roads select line, the bad geological province should be evaded. Its impact on soil and water loss mainly shows as the new soil erosion caused by taking over land for use and the cubic metre of earth and stone project, etc. When the road is newly built, the surplus discarded soil and residue should be transported to the discarded soil and residue field that the railway project plans to build or take temporary centralized stacking. The both sides of the permanent road set up drainage ditch. The partial access road is used forever. After the project is completed, it is guaranteed that road surface is even and the road is expedite.

In the projects in order to prevent the access road from water erosion, the road surface adopts mud and broken stone one (the former soil road of the widen sector all carries out to be rebuilt, and adopts mud and broken stone road surface). The broken stone and mud

of 20 cm thick covers on it and then is made even and compact. The intercepting ditch of 30 cm wide is set up on both sides of the access road. According to the survey of soil and water loss of the access road of the highway and railway project, its road surface is slight erosion, and is relatively lower than the current erosion intensity.

## 6 Conclusions

It is indicated from the research that the construction period of the project may aggravate soil and water loss in the area where the project locates. The hazard of soil and water loss caused is shown as follows:

(1) The permanent occupied land of the projects destroys former vegetation and forms new topographical features. If the corresponding measures are not taken to resume vegetation, soil and water loss will aggravate constantly and endanger the safe of the project and farmland facility around.

(2) The digging of the railway moat and the filled embankment form high steep artificial slope. Without any protection, the slope erosion will silt the discharge ditch of both sides of the road bed to make drain water not smoothly and wash off the farmland of both sides.

(3) The discarded soil and residue of the road bed and tunnel pile up in gulch and river beach. If there is not effective protection measure, the storm rainfall is rushed into the river channel to endanger the safe of flood prevention of river channel.

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