

Design of Biological Protection of Side Slope of Roadbed on Luojie Express Highway and Its Implementation

*Yang Jianfeng*¹ *Wu Qing*¹ *Yang Chunxia*¹ *Wang Jinrong*² and *Gao Wei*³

¹Institute of Hydraulic Research, Yellow River Conservation Commission, Zhengzhou Henan 450003;

²The Center of Laboratory, Academy of Agriculture Sciences, Zhengzhou Henan 450002;

³The Develop Company of Science and Technology, Academy of Agriculture Sciences, Zhengzhou Henan 450002

Abstract: The protection of side slope of roadbed on Luojie Express Highway used by engineering measures of biological protection instead of by traditional cement grillage protection is suitable to the developing situation of express highway construction at present and demands of environmental protection, soil and water conservation and afforesting beautification etc by the state. From saving the capital investment of express highway, reducing rigid protection cost, improving landscape along highway, guaranteeing safety of road and driving, preventing loss of soil and water, lowering noise and powder pollution, and increasing economic benefits, it is a taste and exploration with green passage of unique style built by Luoyang Highway Management Bureau, it is of important guiding significance in other express highway construction hereafter.

Keywords: express highway, side slope of roadbed, biological protection, soil and water conservation

The expressway of Luoyang section in Luoyang boundary is situated in the vertical section of western Luoyang on “Two vertical and two horizontal main trunks” of highways network in Henan Province. It is a national key project of the highway construction of “the Tenth Five-Year Plan”. It will become a main passageway linking the mid-western and southeast and a big artery of highway on developing urban and rural economy around the areas and vitalizing both Henan and Anhui Provinces’ economy after constructing. Luoyang section’s expressway starting from Daliwang village of Baimasi town of the eastern suburbs in Luoyang city to Maying village of Da’an countryside in Ruyang county totals 49.949km. Among which, the section length in tiny rolling areas of plain is 16.6km, the section length in heavy rolling areas of mountain ridge is 33.349km, 384.26hm² of land is taken up permanently. The standard of road design is an expressway with four two-way lanes. The total investment of the project is 1.2395 billion yuan. It is planned that it is completed and open to traffic in the end of 2002.

1 Natural situation

1.1 Geographical conditions

A vast of loess and deep soil layer are the main geomorphologic characteristics of the expressway through tiny rolling areas of plain; the gully crisscrossed, the earth’s surface cut seriously and broken abnormally are the main geomorphologic characteristics of the expressway through heavy rolling areas of mountain ridge. The landform characteristics along the expressway are with uneven landform, big undulate relief, and serious hydraulic erosion of the earth’ surface and great disparity in the valley slope in various rivers. The project geology is divided into the project geologic area of loess (pile No. k0+000—k19+300); the low mountain hard project geologic area (pile No. k19+300—k20+840) and the rolling soft project geologic area (pile No. k20+840—k49+949).

1.2 Hydrology and meteorology

The expressway construction regions belong to the climate zone with warm and continental

monsoon, whose mean annual temperature is 14.3°C. The temperature in January is the lowest, -0.10°C; the temperature in July is the highest, 26.8°C; the accumulated temperature of activity $\geq 10^{\circ}\text{C}$ is 4,000°C—5,000°C, the frost-free period is 200d—220d. This climate is suitable to agricultural production and various plants growth. The northwest wind is prevailing in winter and the southeast wind is prevailing in summer with mean annual wind velocity 2.3 m/s. The mean annual rainfall is 620 mm. The precipitation is concentrated in summer, mainly from July to September, with big strength, accounting of 60% or so of precipitation in the whole year and mostly being rainstorm. *The map in common use of hydrological calculation of hydro project in Henan Province* shows that the maximum rainfall is 220 mm/24h of rainstorm occurred in a century in this region.

1.3 Vegetation situation

Grain crops, such as wheat, corn and sweet potato, are planted widely; the main cash crops are cotton, tobacco leaf, peanut, rape and sesame etc in this region. The main forest and fruit trees include elm, mahogany, paulownia, poplar, locust, Chinese catalpa, Chinese pine, Chinese honey locust, oriental arborvitae, metasequoia, cryptomeria, apple, pear, peach, apricot, persimmon, Chinese prickly ash and fig, etc. The wild plants are dandelion, algae, wild Lucerne, beggar-ticks, green bristle-grass, painted euphorbia, cogon-grass, water pea and phellodendron. According to an on-the-spot investigation, there are few vegetation along the expressway and the cover degree of natural vegetation is lower, less than 8% commonly. The surface is uncovered, the loss of soil and water is serious in most section.

1.4 Characteristics of loss of soil and water

The distribution of loss of soil and water is wide, with big lost strength, taking surface erosion and gully erosion as main. In the tiny rolling areas of plain, the type of loss of soil and water is to take hydraulic erosion as main, the main mode of soil erosion is surface erosion, the modulus of soil erosion is 200t—1,000t(km² • a), belonging to light erosion region. In the heavy rolling areas of mountain ridge, the type of loss of soil and water is to take interactions between hydraulic erosion and gravitational erosion as the principle thing, taking surface erosion as the principle thing on slope surface and gravitational erosion as main in gully. The modulus of soil erosion is 4,000t—6,000t(km² • a) commonly, belonging to severe erosion region.

2 Design and implement of biological protection on side-slope

2.1 Design basis, principle and scope

Basis:

(1) Design contract of biological protection on side-slope on roadbed of expressway in Luoyang section of Luoyang boundary and appendix.

(2) Technical standard of comprehensive harnessing on conservation of soil and water GB/T 16453.1—16453.6-1996.

(3) Technical standard of scheme on conservation of soil and water in developing-constructing project SL-204-1998.

(4) Design standard of environmental protection on highway.

(5) Construction map design on two stages of expressway in Luoyang section of Luoyang boundary (7 books in all).

Principle:

(1) “Suiting measures to local conditions, setting up defenses based on disasters, laying stress on the key points, paying attention to benefits”.

(2) “Proceeding from realities, to be suitable for land, trees and grass”.

(3) “Safety, save, economy and beauty”.

(4) “Harnessing comprehensively, taking protection as the principle thing and harnessing as an assistant”.

- (5) “Unifying economic benefit, social benefit and environmental benefit”.
- (6) “Unifying afforestation of protecting environment and improving environment”.

Scope:

- (1) The original design of contract sections 1—8B in Luoyang section of expressway in Luoyang boundary is the side-slope of protective section with concrete grille.
- (2) The roadbed fill of contract sections 1—8B in Luoyang section of expressway in Luoyang boundary is 3m section smaller than of the side-slope and side-slope with soil in excavating section.
- (3) The open ground between the side ditches of filling (excavation) sections of contract sections 1—8B in Luoyang section of expressway in Luoyang boundary and requisition land.

2.2 Design objective

- (1) The protective problems on side slope in the near future (1a—2a) and at a specified future date (2a—3a), to ensure side slope steadiness, to prevent soil and water from losing and side slope from collapsing, to ensure steadiness on roadbed, to safeguard safety and snuggerly for driving.
- (2) The landform and vegetation damaged by constructing expressway are recovered through afforesting, to lower driving noise and dust pollution, to protect and improve natural ecological environment, to construct a beautiful natural landscape so as to make its surrounding landscapes merge naturally for the physical and mental health of the drivers-passengers and residents along expressway line.
- (3) Under the premise of satisfying protective function and afforesting-beautifying functions on the side slope, to consider the selection and plantation of economic timber trees, to attain goal for self-restraint, protecting water source and increasing storage of wood and obtaining certain economic benefits.

2.3 Determination of design scheme of biological protection on side slope

According to the contract requirements and actual requirements of protection on side slope, on the basis of stipulations about national Law on Environmental Protection, Law on Conservation of Soil and Water, Law on Highway and Design Standards on Environmental Protection of Highway, the scheme of biology on side slope in Luoyang section of Luoyang boundary have been finally determined through proof of optimization on variety of schemes and verification of analog simulation experiment of the maximum rainstorm in a century. The practical contents of the scheme are shown in Table 1.

The explanation on the general design of the scheme:

(1) The side slope of filling soil: the layout of biological measures should be considered comprehensively from protective role, afforesting-beautifying effect and driving safety on the side slope. The selection of variety of plants should be considered from biological formation, habits, suitability, main function and use, and nursing. Through optimum selection, the mixed sowing with false indigo and Bermudagrass has been selected, they have well-developed root system, fast growth, early closure, cold resistance, drought resistance, barren resistance, good effect of strengthening slope, controlling the loss of soil and water well and stabilizing roadbed effectively. The early vegetation coverage of slope surface is increased by optimum combination with shrub and grass. In this way, the problems of protection on the side slope in the near future and at a specified future date solved by the contract requirement will be satisfied.

(2) The side slope of filling sandy gravel: the difficulty of biological protection is very great, which differs from one of the side slope of filling soil on measures layout to some extent. The protection on the side slope adopted three dimensional vegetation network with planting grass of new technique of biological protecting slope has been carried out, considering from distribution of sandy gravel of the side slope filling, conditions and the loss of soil-water produced and sliding-collapse occurred easily. The nutritional soil with 0.2m is first covered on the slope surface, the three dimensional network is laid from slope top to foot when implementing practically. After the soil is covered in the network, the seeds of “Hall fescue of 20%+Bermudagrass of 60%+Perennial ryegrass of 20%” mixed are sowed. In order to attain the aim of quick protection, the sod of the three-dimensional network reinforced can be used. The sod is first replanted then laid on the side slope protected after it has been shaped. Therefore the problems of protection on the side slope with sandy gravel in the near future and at a specified future date will be solved.

Table 1 Design scheme of biological protection on side slope of roadbed in luoyang section of luoyang boundary

Mark section	Design position	Type of filling and excavating	Slope ratio	Variety of plants selected	Ecological type	habits	Main uses	Standards of Nursery-grown plants	Row spacing of plant
No.1	Side slope	Filling soil	1:1.5	False indigo Bermudagrass	Deciduous shrub Herb	Cold resistant, Drought enduring, Barren resistant	Land cover and protecting slope	1-year growth Grass seeds of last year	0.5m×0.5m broadcasting
			1:1.75						
	Road of protective slope	Filling soil		Crape myrtle Hollyhock	Deciduous small arbor Green shrub, Deciduous shrub,	Sunshine, cold resistant, Strong soil suitability	Ornamental plants, Afforestation for gardens, Flower fence	3-years growth 5-years growth 3-years growth	Individual spacing of 5m
	Open ground between side ditch and requisition land			Black walnut Chinese prickly ash	Deciduous arbor, Deciduous small arbor Deciduous shrub,	Strong suitability, Drought- enduring, Saline-alkali endurance	Timber forest, Thorny fence, Biological barrier	2-years growth 2-years growth 2-years growth	Individual spacing of 2m Individual spacing of 1m Individual spacing of 1m
No. 2	Side slope	Filling sandy, gravel	1:1.5	Three dimensional vegetation network (Bermuda root, rye grass)	Lawn cover	Cold resistant, Drought enduring, Disease assistant, Much tillering	Protection of slope surface, vegetation Strengthening and protecting slope	Grass seeds of Last year	20 g/m ² —25 g/m ²
			1:1.75						
	Road of protective slope	Filling sandy,gravel		Oleander, Plum with red leaves, Chinese juniper	Green shrub, Deciduous small arbor, Green arbor	Drought resistance, Saline-alkali endurance, Strong soil suitability, Sunshine	Flower shrub, Ornamental plant, Afforestation with conservation	3-years growth 3-years growth 5-years growth	Individual spacing of 5m
	Open ground between side ditch and requisition land			Poplar in Europe and America ¹⁰⁷ Chinese prickly ash	Deciduous arbor Deciduous shrub Deciduous shrub	Strong suitability, Drought resistance, Saline-alkali endurance	Timber forest, Thorny fence, Biological barrier	2-years growth	Individual spacing of 2m, Individual spacing of 1m, Individual spacing of 1m,

Continued

Mark section	Design position	Type of filling and excavating	Slope ratio	Variety of plants selected	Ecological type	habits	Main uses	Standards of Nursery-grown plants	Row spacing of plant
No. 3	Side slope	Filling sandy, gravel	1:1.5	Three dimensional vegetation network (Bermuda root, rye grass)	Lawn cover	Cold resistant, Drought enduring, Disease assistant, Much tillering	Protection of slope surface vegetation, Strengthening and protecting slope	Grass seeds of Last year	20 g/m ² —25 g/m ²
			1:1.75						
	Road of protective slope	Filling sandy, gravel		Oleander Plum with red leaves Chinese juniper	Green shrub, Deciduous small arbor, Green arbor	Drought resistance, Saline-alkali endurance, Strong soil suitability, Sunshine	Flower shrub Ornamental plant Afforestation with conservation	3-years growth 3-years growth 5-years growth	Individual spacing of 5m
	Open ground between side ditch and requisition land			Poplar in Europe and America ¹⁰⁷ Chinese prickly ash	Deciduous arbor Deciduous shrub Deciduous shrub	Strong suitability, Drought resistance, Saline-alkali endurance	Timber forest, Thorny fence, Biological barrier	2-years growth	Individual spacing of 2m Individual spacing of 1m Individual spacing of 1m
No. 4 — No. 5	Side slope	Filling soil	1:1.5	False indigo Bermuda root	Deciduous shrub herb	Cold resistant, Drought enduring, Barren resistant,	Land cover and protecting slope	1-year growth Grass seeds of last year	0.5m×0.5m broadcasting
			1:1.75						
		Filling stone of excavation	1:0.5 1:0.7	Boston ivy	liana	Shade resistance, Cold resistance, Strong suitability	Vertical afforestation, Grid fence	2-years growth	Individual spacing of 0.5m
	Open ground between side ditch and requisition land			Dry willow and elm Chinese prickly ash	Deciduous arbor Deciduous shrub Deciduous shrub	Fast growth Strong suitability, Drought resistance and saline-alkali endurance	Shade tree, Shelter-forest, Garden shade tree, Thorny fence defense	2-years growth	Individual spacing of 4m Individual spacing of 1m Individual spacing of 1m

Continued

Mark section	Design position	Type of filling and excavating	Slope ratio	Variety of plants selected	Ecological type	habits	Main uses	Standards of Nursery-grown plants	Row spacing of plant
No. 6 — No. 8A	Side slope	Filling soil	1:1.5	False indigo, Bermuda root	Deciduous shrub herb	Cold resistant, Drought enduring, Barren resistant	Land cover and protecting slope	1-year growth Grass seeds of last year	0.5m×0.5m broadcasting
			1:1.75						
No.8B	Side slope	Filling stone of excavation	1:1	Boston ivy	liana	Shade resistance, Cold resistance, Strong suitability	Vertical afforestation, Grid fence	2-years growth	Individual spacing of 0.5m
		Filling stone		Three dimensional vegetation network (Bermuda root, rye grass)	Lawn cover	Cold resistant, Drought enduring, Disease assistant, Much tillering	Protection of slope surface vegetation, Strengthening and protecting slope	Grass seeds of Last year	20 g/m ² —25 g/m ²
No. 6 — No. 8	Open ground between side ditch and requisition land			Locust with fast growth Chinese prickly ash	Deciduous arbor Deciduous shrub Deciduous shrub	Strong suitability, Sunshine, Growing fast	Shade tree, Shelter-forest, Garden shade tree	2-years growth	Individual spacing of 3m Individual spacing of 1m Individual spacing of 1m

(3) Road of slope protection: the small arbor or shrub with flowers, leaves and evergreen on measures layout with strong suitability, easy management, small investment, pollution-powder resistance, easy breeding and transplanting, strong resistance of plant diseases and insect pests, and good landscape effect is chosen on biological measures layout in order to afforest and beautify, and improve-protect environment. The good tree varieties in garden afforest, including hollyhock, Chinese juniper, crape myrtle, *Hibiscus syriacus*, oleander and red-leaf pump will be adopted.

(4) The soil side slope and side slope with stone in excavating section: the vertical afforest on high-steep side slope is mainly considered on soil side slope in excavating section. The methods of putting seeds into ready-dug hole and direct seeding are adopted on measures, taking Boston ivy of climber planted as the principle thing, considering the direct seeding of grasses suitably, such as Bermudagrass, Crown vetch, Tall fescue. The stability of side slope, planting conditions of plants and on the spot formation-geology are mainly considered on the side slope with stone (8B section), the early quick protection and compound protection on the side slope are carried out by “the three dimensional network+sod reinforced”.

(5) The open ground between side ditch and requisition land: proceeding from the point of view on rational utilization of land, afforest-beautify around biological environment, a variety of timber tree with easy breeding, quick growth, narrow crown, straight and tall trunk, strong contrary resistance, good quality, high storage and standing timber in unit area are chosen on designing schemes. The black walnut, Europe-America poplar and locust with quick growth are adopted. Some local tree varieties, such as elm and dry willow are also adopted combining with local conditions. The biological fence with Chinese prickly ash and yellow thorn plum planted inside closure net is taken as the second defense of road closure or with the biological closure instead after the protective net by iron rust.

The cross section maps of biological protection design on the side slope of other's roadbed in Luoyang section are omitted.

2.4 The experimental verification and optimum selection of schemes on side slope's protection and design

According to the requirements of the design contract appendix, the design standard on side slope's protection should satisfy the demands of controlling the scouring of a rainstorm occurred in a century and without eroded ditch above 20cm on the side slope. In order to verify the protective effects of design scheme and the rationality, safeness, feasibility and science of biological measures layout, and provide the theoretical basis of scheme implement for the construction units, we have carried out the experimental simulations of rainstorm scouring occurred in a century on various sections (No. 1—No. 8) Fig.1 and Fig.2, ratio of various side slopes (1:1.5, 1:1.75, 1:2), various filling (drab loess, sandy gravel, limestone loess) and various measures of biological protection (shrub, grass) in Luoyang section of the expressway by the experimental method of simulating artificial rainfall and runoff scouring. The experimental simulating system is composed of experimental model simulation, artificial rainfall simulation and runoff scouring simulation of the slope surface. The similarity principle is the base on experimental theory. There are 12 set of simulating experiments made in all, 6 set in a time, 2 times of comparison. It is shown from the experimental results that

(1) On stabilizing and protecting the side slope, to use the biological protective measures instead of traditional grille protection of cement is feasible in theory and technique through experimental verification.

(2) The protective role of plant measures is a result of common action on plant root system and a part beyond ground. The stems beyond ground play a certain role in lowering kinetic energy of raindrop, reducing splash erosion of land surface, retarding runoff velocity and decreasing scour quantity whereas the plant root system underground plays a decisive role.

(3) The plant root system plays a leading role in the stability of side slope and anti-scouring protection. The mutual twines between root systems can solidify the earth mass of land surface effectively, raise anti-eroded capacity of the side slope and protect it; at the same time, the root system plays an important role in delaying, slowing down and shortening flow and sediment yield of side slope.

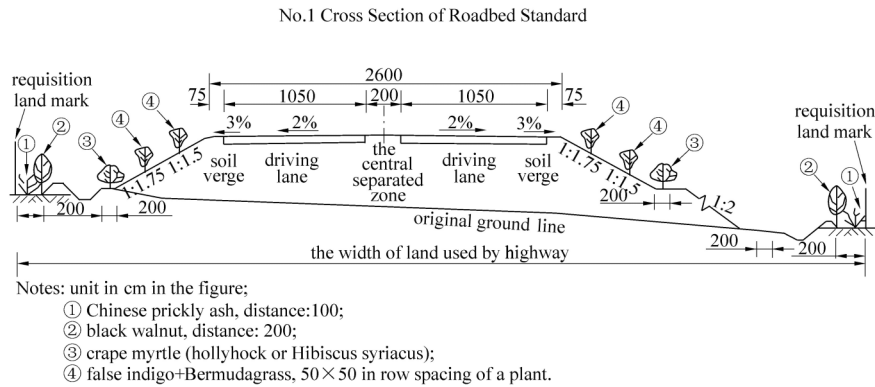


Fig. 1 Cross section of biological protection design on the side slope of No. 1 roadbed in Luoyang section

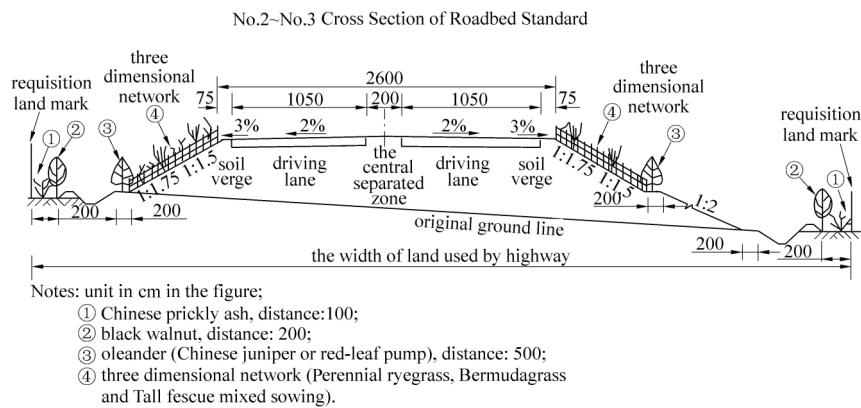


Fig. 2 Cross section of biological protection design on the side slope of No. 2—3 roadbed in Luoyang section

(4) The anti-scouring capacity of the side slope with various slope ratio and fillings is different. The protective effect on various plants measures is different. To reach the protective standards of a rainstorm in a century defended must make the vegetation degree of side slope coming up to 80% above, and the rational measure arrangement and optimum composition of schemes can satisfy the demands of protective design.

3 Scheme's implement

The biological protection on the side slope in Luoyang section No.1—No.8 of expressway and the protection between side ditch and requisition land mark No.1—No.3 will be finished from March to May in 2002. The protection between side ditch and requisition land mark No.4—No.8 will be finished in 2003.

4 Conclusion

The roadbed side slope with biological protective measures is suitable to the developing tendency of the expressway construction in the future and the national demands on environmental protection, conservation of soil and water, and afforest-beautifying. An attempt and exploration carried out is of momentous current significance proceeding from improving landscape along expressway, afforest-beautifying, ensuring safety of road and driving, preventing loss of soil and water, lowering noise and powder pollution, saving investment and raising economic benefits.

References

- [1] JIAO Juren, JIANG Dewen, WANG Zhiguo, *et al.*, The Developmental Construction Project: Conservation of Soil and Water. [M]. Beijing: The Legal System Press in China, 1998.
- [2] HAN Liebao, YANG Bei, DENG Jufen, *et. al.* Lawn, Grass Seeds and Variety. [M]. Beijing: The Forestry Press in China, pp. 58-96. 1999.
- [3] LIANG Yongji, WANG Lianqing. The Gardens and Land Green Design of Road and Square. [M]. Beijing: The Forestry Press in China, pp. 98-104. 2001.
- [4] LIN Chenggu. Soil Science. [M]. Beijing: The Agricultural Press, pp. 213-218. 1989.
- [5] Li Xueren. Research on Geomorphologic Characteristics of Loess and Rational Utilization of Land in Yuxi. [J]. The Conservation of Soil and Water in China, pp. 9-13. 1990 (3).
- [6] ZHU Lianqi. Effect of Soil Erosion on Sustainable Development of Agriculture in Rolling Loess Mountains of Yuxi. [J]. Journal of Conservation of Soil and Water, pp. 41-43. 2001. 15 (5).