

BEST PRACTICES FOR THE SHENNONGJIA-YICHANG ECOLOGICAL HIGHWAY UPGRADING PROJECT IN CHINA

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ABSTRACT

The Shennongjia-Yichang Highway, located in the mountainous region in the northwest of Hubei province, is a demonstration eco-highway project in China. The highway connects Yichang City, where the famous Three Gorge Dam is located, and the Shennongjia Forest District, a world-famous national nature reserve listed on UNESCO network of Man and the Biosphere Program. The highway runs along the Fragrant Creek in a narrow canyon. This paper reviews the best practices taken to mitigate the environmental impact during the construction of the highway upgrading projects, in hope of contributing to an understanding the on-going efforts of environmental conservation in China.

The practices involves the measures adopted to optimize the route design to conserve the nature and to enhance the coordination of the highway facilities with the environment, the innovative and integrated re-vegetation technologies for the roadside slopes, the landscape evaluation and harmonization planning. Firstly, after a fierce debating on the probable tremendous environment impact on the nature resulting from a previous optional freeway scheme, government finally decided to upgrade the road to a class II eco-highway. Secondly, horizontal and vertical alignment coupling of the line type were adjusted upon traffic and geological safety analyses, requisite land value assessment, and landscape protection and optimization to minimize the cut and fill. Thirdly, special techniques such as half-width bridges, viaduct and tunnels, curve line, hanging groove over river were widely used in section through the canyon to minimize the environmental impact and facilitate ecological restoration. Furthermore, previous roadbed that are not used in new roads were mostly utilized for rest areas, sightseeing areas, or other service facilities. Asphalt concrete of the previous road surface, cut trees and stones was recycled and reused. In addition, public participation on road landscape evaluation and harmonization planning were achieved using questionnaire survey and photo grading. Sightseeing area, relief sculpture, and other facilities are set up to improve the convenience and comfortability for the tourists. Plants for slope protection were selected based upon experiment and assessment on species' adaptation ability. Re-vegetation techniques including external-soil spray seeding, planting in dug holes, vertically planted liana on net covering slope, ladder-like hollow brick greening and L-shape concave greening beside masonry retaining wall, and many other techniques were used to enhance the performance of the roadside re-vegetation. Multi-agency including owner, local governments, design units, institutes, contractors, consultant units, and the public individuals played important role during the construction.

The construction of the Shennongjia-Yichang eco-highway marked a monumental progress in resource saving, harmonization of road and the nature in China. The ideas and methods developed during the construction have been extended to similar regions.

KEY WORDS Practices, ecological highway, Shennongjia-Yichang, flexible design, re-vegetation, landscape evaluation

INTRODUCTION

The Shennongjia-Yichang Highway, G209, located in the mountainous region in the northwest of Hubei province. It connects Yichang City, where the famous Three Gorge Dam is located, and Shennongjia Forest District, a world-famous national nature reserve listed on UNESCO network of Man and the Biosphere Program (MAB). The original road, was 7-8.5m wide. The old road always caused serious traffic jam, especially in the

tourism season. So the residents lived nearby had more and more complaints about the road condition.

Therefore, the section of the highway from the Muyuping town in the Shennongjia Forest District, to Xingshan County of the Yichang City, was rebuilt and extended in 2006-2008 by Hubei Provincial Highway Administration. It is 52.96 km long, runs along the Fragrant Creek in a narrow canyon. Because there are many human heritages and scenic spots located near the highway, such as the Hometown of Zhaojun Wang, who is one of the four most famous ancient Beauties in China, the Mysterious Dragon Cave and so on, upgrading project attract so much public attention.

The Highway Rebuilt and Extended Project was listed as a demonstration eco-highway project in China. Many researches and practices were carried out to protect the natural and social environment along the highway, including flexible design, landscape improvement and re-vegetation.

This paper reviews the best practices taken to mitigate the impact during the construction, in hope of contributing to an understanding the on-going efforts developed for natural conservation in China.

FLEXIBLE DESIGN AND ENVIRONMENT PROTECTION

Making a Suitable Technical Classification

During the feasibility study period, the planning of a two-lane highway vs. a four-lane freeway was debated fiercely involving the provincial governments, the local governments, highway planning units, experts and scholars. Based on detailed investigation and scientific analysis, the highway was finally determined to be rebuilt to a class II highway with two lanes, according to social and economic demand, road network condition and future requirement.

Compared with a four-lane freeway, the land use of the two-lane highway is only 41.3 hectare, saved valuable land more than 208.7 hectare. Therefore, the investment is reduced from over 2 billion RMB to only 384 million RMB. Less cut and fill needed, probable tremendous harm to the nature was avoided.

Better use of the Previous Roadbed

Symmetrical and unsymmetrical route planning methods are used for better using of the previous roadbed. The route types of S-curve, oval curve and combining curve are widely used. Ninety four curves with a total length of 41.06 km, are planned in the route, covering 77.5% of the whole highway.

The width of the roadbed varies from 8.5 m to 10 m according to the limit of the environment. 5 tunnels, 20 bridges, 11 half-width bridges (fig. 1), and 6 cantilever beam-slabs were used flexibly in different part of the route. There are 44.1km of the upgraded highway built on the previous roadbed, using 83% of the previous roadbed.

If the roadbed is not coupled to the new route due to linear requirement, the abandoned roadbed is planned to be built for rest area, sightseeing area or others for highway service. Fifty seven roadside rest areas or safety zones, 8 sightseeing areas (fig. 2) are built along the upgraded highway.



FIGURE 1 Half-width bridge and half-width previous roadbed



FIGURE 2 Sightseeing area built on the previous roadbed

Conservation of the Nature

Horizontal and vertical alignment coupling of the line type were adjusted upon traffic and geological safety analyses, requisite land value assessment, and landscape protection and optimization to minimize the cut and fill.

Cliff

Cliff was preserved through the design of bridges, half-width bridges, and cantilever beam-slabs. Some cliffs were carefully chiseled to widen the roadbed instead of explosion.

Big Trees

Roadside big trees were carefully protected, through the measures such as binding tree trunk with straw rope, building a retaining wall near tree stump, marking with protection signs to the contractors and so on.

Tea Yard

Tea yard along the highway was not disturbed by the highway construction.

Historic Heritages and Scenery Spots

Historic heritages and scenery spots were well conserved through route planning and carefully construction. Some of them were designed to be one part of the roadside landscape, such as the Mysterious Dragon Cave mentioned below.

Resources Recycling and Reusing

During the construction, many resources were recycled and reused, including the asphalt concrete, cut trees, stones etc.

Asphalt Concrete

Asphalt concrete of the previous road surface was recycled and paved on the ramp of interchange, or on the countryside road nearby.

The particle of asphalt concrete made from the previous road surface was attempted to be used as a material for External-Soil Spray Seeding. After many indoor test and field test, 10% of the particle of asphalt concrete was recommended to be added into the external-soil. It is proved that the particle of asphalt concrete will help the growth of vegetation as it is beneficial to absorb the quantity of heat, especially in the early period after seeding.

Cut Trees

Some trees had to be cut during the highway rebuilding and extending. The trunks of them were used to build the retaining walls on the cut slopes (fig. 3), which had a natural appearance. Other branches and leaves were crushed and composted for making the organic fertilizer, to be used for seeding or planting.

Stones

Small stones were used for curbing the parking area. Selected large stones were designed as the road signals (fig. 4), marking the highway bridge, or indicating the scenic spots nearby. Hard rocks were crushed to sand, which could be used as a material for pavement, or for a kind of hollow brick for slope protection.



FIGURE 3 The trunks of cut tree were used to build retaining walls



FIGURE 4 Road signal made by large stone

LANDSCAPE AND TOURISM FACILITY

Landscape Evaluation

In order to find out the attraction to tourists, the quality of roadside view was investigated and assessed. Combined indices include the visual quality of highway and the environment, the attraction of humanity and culture.

Chosen photos and a survey questionnaire were designed for investigation. Seventy one photos represent 12 visual aspects in the canyon such as vegetation types (arbor, shrub or grass), slope protection types (engineering, vegetation, or combined), etc. The visual qualities were scored by drivers, visitors, residents, and students.

According to the investigation, the tourist resorts have the highest value of view, attracting lots of visitors. There are many resorts near the highway in the canyon, with a distance of 10m to 4000m outside the Right-of-way. Among them, the famous resorts include the Shennongjia National Reserve, the Headstream of the FrAGRANT Creek, the Shennong Altar, the Natural Stone Bridge, the Mysterious Dragon Cave and Village of Zhaojun. The cliffs, mountains, vegetation, water falls after rain have very good views.

There are also some bad landscaping spots along the highway, mainly disturbed by human being. Among them, the bad views include disordered building, the waste dump, the chaos network of electric wire along the road, the spotted water power plants which break the water flow in the creek, and the dark exhaust gas emitted from a chemical plant.

Landscape Improvement

Based on the result of landscape evaluation, those bad view spots were kept away from the upgraded highway. For example, a section of roadbed and a tunnel was newly built to keep away from the chemical plant, which located in the beginning of the highway at Xingshan County, which was difficult to be closed or re-located.

The land use planning was adjusted for the residential area along the highway. The disordered power supply facilities along the highway were rearranged and the electric cables were put into the underground pipes after highway construction.

Several measures were taken to make a better view on the highway's sections which have good landscape resources. Roadside shrubs which shelter the eyesight for a good view were cleared away, wild flower and turf were planted instead. The cable safety fence and the steel safety fence (fig. 5) were set up to replace the cement concrete safety guard bar.



FIGURE 5 The cable safety fence (left) and the steel safety fence (right)

Tourism Facilities

The Xingshan County, is the hometown of Qu Yuan, who is regarded as a famous poet, a politician, and a patriot. It is also the hometown of Zhaojun Wang, who is considered to be one of the four most Beauties in Chinese long history, married a king of minority to ameliorate the relationship of Han Dynasty with other Minority Kingdom.

The name of Shennongjia came from a historic legend about Shennong, who was said to climb up cliff by ladder to seek Chinese medicine to cure people. One attraction of Shennongjia is the mist of salvage human.

Some sculptures are made on the highway to reflect the splendid culture in the area. For example, the sculptures of four famous people mentioned above, Qu Yuan, Zhaojun, Shennong, and salvage human, are showed on a rest area. A retaining wall was designed to emboss with the famous Han Ethnic Epic, *Darknight Biography* (fig. 6). A get-through salvage man shape sculpture and a tunnel shape bridge connected a rest area with the entrance of the Mysterious Dragon Cave on the other bank of the creek (fig.7).

Introductions of the local history and culture were made at some sightseeing areas or rest areas to help the visitors to broaden the knowledge.



FIGURE 6 Embossed the Han Ethnic Epic *Darknight Biography* on a retaining wall



FIGURE 7 A Way from the rest area to the Mysterious Dragon Cave

SLOPE PROTECTION AND REVEGETATION

Slope Stabilization Measures

Several principles are adopted to slope protection:

- If the cut or fill is stable and safe, protecting the slopes by vegetation is the first choice.
- The enforcement of slope was greatly encouraged to combine the engineering measure with vegetation. Re-vegetation in the framework is a main method for fill slope protection.
- If the stone is hard enough, let-the-rocky-slope-be-itself is also encouraged.
- Defensive steel network is widely used in rocky slopes to prevent from the falling stones.

Selection of Plant Species for Re-vegetation

Selection of the Plants Suitable For Seeding

To select suitable plants for the area, an experiment lasted 3 years was set up before the highway construction near the city of Yichang based on investigation of the local plants.

Nineteen woody plants and 8 herbaceous plants were introduced to a fill slope plots, and investigated for their early competition ability, adverse environmental stress hardness and growth potential, and classified based upon hierarchical cluster analysis and subordinate function value.

The experimental plants can be classified into five categories: *Indigofera pseudotinctoria* and *Solanum deflexicarpum* have the best performance; *Desmodium sinuatum*, *Cynodon dactylon*, *Melia azedarach*, *Robinia pseudoacacia*, *Lespedeza cunecta*, *Vitex negundo*, *Paspalum notatum* rank the second; *Festuca arundinacea*, *Eragrostis curvula*, *Cudrania tricuspidata*, *Rhus chinensis*, *Dodonaea viscosa*, *Senna obtusifolia*, *Rhamnus utilis*, *Ailanthus altissima*, *Lotus corniculatus* rank the third; *Pterocarya kunth*, *Kummerowia stipulacea*, *Sapiu sebiferum*, *Eremochloa ophiuroides*, *Trifolium repens* rank the forth; *Pinus massoniana* Lamb rank the poorest.

Selection of Suitable Plants for Propagating in Nursery

A nursery was built to propagating some indigenous plants not suitable for seeding. The branches of indigenous plants were carefully cut and planted in the nursery.

Those plants bred in the nursery were designed to be planted at some key scenic spots, imitating the natural community component, to create a more natural performance. The plantation was done on those slopes not too steep.

Plant mixture

Fast adapted mixture and pioneered mixture of herbaceous and woody plants have the best performance of soil and water conservation in this area, such as *Festuca arundinacea* + *Festuca rubra* + *Indigofera pseudotinctoria* + *Lespedeza cunecta* + *Alnus cremastogyne* Burk + *Robinia pseudoacacia*, *Festuca arundinacea* + *Festuca rubra* + *Cajanus cajan* + *Tephrosia candida* + *Crotaria assamica*, *Indigofera pseudotinctoria* and *Robinia pseudoacacia*.

Mixture of *Festuca arundinacea* + *Festuca rubra* + *Lespedeza cunecta* + *Indigofera pseudotinctoria* + *Amorpha fruticosa* has the largest soil loss amount than other mixture.

Above ground biomass related significantly with soil loss, other than coverage, plants density and other indices. Plant with fast above ground biomass accumulation should be taken into account for better re-vegetation.

Re-vegetation techniques

The types of roadside slope include hard rocky, soft rocky, soil, and soil/stony. Slope protection and re-vegetation was designed according to the types. Some new techniques including ladder-like hollow brick greening, L-shape concave greening for the masonry retaining wall were carried out in the project.

Fast Establishment of Woody Plants

To prevent the degradation after re-vegetation, the goal of the re-vegetation is to establish woody plants community. Herbaceous and woody plants competition characteristics and predominance of established species were studied to decide the portion of the seed mixture. Woody vegetation was successfully established by taking use of the difference of growth habit. The experiments of the mixtures were estimated based on the plots in Yichang. The balance between species with close growth habit were prone to achieved, such as the balance between *Solanum deflexicarpum* and *Vitex negundo*, *Indigofera pseudotinctoria* and *Vitex negundo*, *Lespedeza cunecta* and *Solanum deflexicarpum*, while mixture with wide gaps of growth habit tend to form single predominance species. Mixture of herbaceous and woody species has better performance than that of common herbaceous mixture in 3a. Artificially re-vegetation had much fewer species, less abundant biodiversity and lower level of soil organic matter compared with natural vegetation. Regulation of competition between herb and wood, mixture mode selection, and temporal and spatial alternation growing methods were advised to establish woody plants.

External-Soil Spray Seeding on Rocky Slopes

Mixture of soil and seeds are sprayed onto the rocky slope with air compressor to re-vegetation. This technology was introduced from Japan to solve the fast re-vegetation of roadside slope several years ago, and was developed to be more adaptable, and could be carried out with a concrete sprayer. Before the spray, the slopes were carefully evened and cleaned off any unstable stones, a metal net was covered on the slope fixed with anchors. Topsoil preserved from the beginning of the construction, some of the wasted concrete mixture from the old roadbed were screened and mixed with compound fertilizer.

In order to save seeds, seeds were not mixed into the soil for spraying. After spraying external soil, seeds were sprayed on the surface of the external-soil by hydro-seeding.

Layered Soil Bag

Layered soil bag is widely used in China on the steep slope protection and re-vegetation. The soil was put into a net bag of geosynthetics made from HDPE. The seeds could be mixed in the soil or sprayed on the bags with hydro-seeding.

Ladder-like Hollow Brick

To minimize the cut of the slope and avoid potential geological hazards, many slopes were cut steeply. Engineering measures such as earth retaining walls, mortar rubble masonry were taken to stabilize these slopes.

Stones cutting from the rocky slope were used to make hollow brick after crushing, cementing. Previously, hollow bricks were used to hold the soil only. The poor performance of the vegetation is due to the poor water condition in the hollow brick, as illustrated in Fig.8 (b). The amelioration was made to layer the hollow brick flat with a seeming of growth space for the plants, which has a good performance (Fig. 8 a).

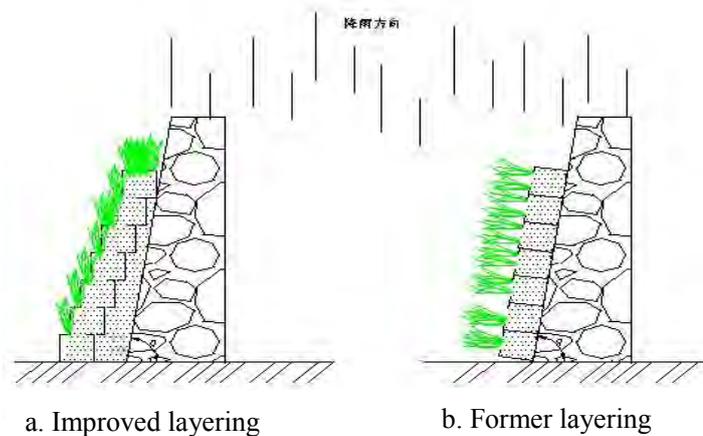


FIGURE 8 Layered hollow brick

Greening on Steep Slopes

Some high and steep slopes are almost vertical to the ground. Two measures are used to green on these slopes:

One is planting liana on the net covering slope. A geo-net was fixed on the slopes by many bolts. Terraces were made on the slope at an interval of 8-10 meters high according to the effective growth length of liane. A groove was dug and was filled with soil on the bottom and each terrace of the slope. Liane was planted, and its Cirrus were tied on the nets to let it grow up (Fig. 9).

The other is planting in dug holes. Holes were dug, and filled with external soil. Shrubs were planted into the holes, herbaceous plants were seeded on the slope by hydro-seeding. However, the result of the



FIGURE 9 Planting liane on the steep rocky slope

experiment was not very good. Nearly 90 percent shrubs died after plantation, but the grass grew fairly good. It would rather be leaving a good opportunity for the wild species to invade on the rock slope than a successful re-vegetation (Fig. 10).



FIGURE 10 Digging hole and filling soil for greening. left: before seeding, right: after seeding

Planting on the Roadside

The highway runs along the Fragrant Creek, a branch of the Yangtse River. In order to prevent the run-off of highway from directly entering the creek, roadside planting were carried out as following.

Subgrade groove was a good practice used along the highway. During the filling of road bed, hollow brick were laid to form a groove on the creek side for the filling of soil and the plantation of shrub and grass (fig. 11, left).

An overhang L shape wall with the bottom beam being placed on the roadbed was adopted in the section where have no enough road surface (Fig. 8, right).

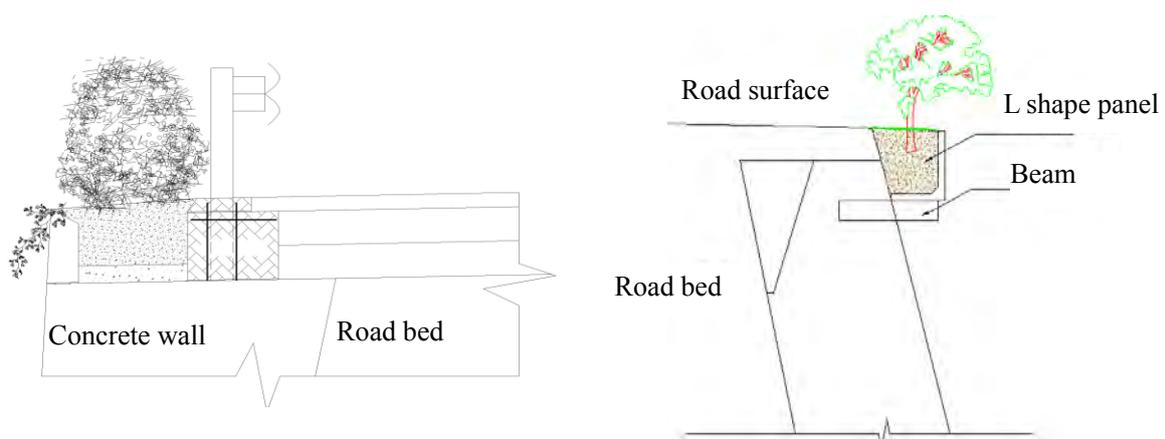


FIGURE 11 Grooving in the roadbed (left)and overhang groove (right) for plantation

THE MULTIAGENCY ROLE FOR THE CONSTRUCTION

The Highway Rebuilt and Extended Project was listed as a demonstration ecological highway project in China. Ministry of Transport, the Government of Hubei Province, pay great attention on the construction of the highway. The chief governor of the province and the minister of MOT made field investigation many times, to give constructive suggestion about the design and construction.

The Hubei Provincial Highway Bureau was appointed to be in charge of the management for the highway construction, under the guidance of the Department of Transport of Hubei Province. A temporal Site Supervision Office was established, responsible for the routine management during the whole process, coordinating among local government, highway designer, engineering contractors, supervision units, consultation units, other units and concerned individual.

The planning, design and construction of the highway was a joint effort of many units. The planning and design was mainly conducted by the Hubei Provincial Transport Planning and Design Institute, consulting with the units including China Academy of Transportation Sciences, Transport Planning and Research Institute, Hubei Provincial Institute of Social Sciences, Hubei Provincial Institute of Art Design, etc.

Training courses were held in the early stage of the construction. Professors, scholars were invited to train all the staff for construction, supervision, and management. Several seminars were held on site to assess the practices and new technologies applied.

DISCUSSION

There is a big population in China, and China is limited by the natural sources. For example, China only has a cultivated land of 120 million hectare. Building highway takes many farmland, so it is very important to save natural resources including farmland, protect natural and social environment during highway construction.

The practices of the Shennongjia-Yichang Highway upgrading project show that we could do better for the social and natural environment. There are many solutions to harmonize the construction of highway with the natural conservation. The solutions include: making a suitable highway planning to keep away the environmental sensitive areas, making flexible design to save cultivated land, making landscaping design to create a comfortable highway view, making re-greening on the disturbed area as possible as we can do, etc.

The construction of freeways in China has been declined gradually in recent years, but the upgrading of lower class roads will see a fast growth. We are sure we could do much better on the resource saving, environmental protection during the highway construction or upgrading in the future.

Despite a great progress has been made on ecological highway during the construction of the Shennongjia-Yichang Highway, it is still needed to carry out new material, new method for ecological highway construction. For example, more species of indigenous plants should be tested, selected and propagated for roadside re-vegetation. And quantitative evaluation method should be worked out for the assessment on highway landscaping. More technologies should be developed to re-vegetating on the steep slopes.

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