ENVIRONMENTAL GEOTECHNICS IN THE PLANNING AND DESIGN OF THE SECOND N-S FREEWAY IN TAIWAN

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Environmental geotechnics in the planning and design of the second N-S freeway in Taiwan

Geotechnique de l'environnement dans la planification et le projet de la deuxième route N-S à Formose

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SYNOPSIS: It was decided that a second freeway be built in the northern region of Taiwan, ROC, with a total length of 86.5 km. Moh and Associates, Inc. was responsible for the planning and design of the southernmost section of 20.4 km, running from Kuanhsi to Hsinchu. During the construction and after completion of the existing freeway, a number of major problems, including landslides and serious settlement, occurred, not only causing disruption of traffic movement, but also having undesirable effects on the surrounding environment. Proper geotechnical study and environmental control evaluation, therefore, became two of the most important factors in the planning and design of the second freeway. This paper describes the procedures and considerations that have gone into the planning and design of the second freeway with respect to geotechnically related environmental control.

1 PROJECT DESCRIPTION

The Kuanhsi to Hsinchu section of the new second freeway in the northern region of Taiwan, ROC, extends from its connection with the preceding section on the northern side of the Fengshan River, at proposed chainage of 66K + 100, to the intersection with the existing freeway in Hsinchu at proposed chainage of 86K + 500. Along the project route, two interchanges, at Chiung-Lin and Hsinchu, are proposed to connect with local roads and the existing freeway.

Geological conditions along the second freeway project are quite complex, including hill areas, terraces,and recent alluvial plains, and encompassing extreme differences in elevation. Most of the geological formations are composed of interlayered sandstone, shale, mudstone and gravel. The engineering properties of these formations are for the most part, weak, poorly cemented, with high permeability and low slake-durability. These formations are easily weathered and eroded.

Based on the results of the geological field reconnaissance, aerial photo interpretation and geophysical exploration, numerous potential disaster areas were identified along the proposed route. These include fault zones, synclinal axis,recent landslide areas, colluvial deposits, headward erosions and bank erosions. All of these areas require proper treatment in order to maintain highway safety and to minimize environmental impact. Extreme variations in topography make deep cuttings and high embankments unavoidable. Suitable landscaping to restore the original environment is, therefore, necessary.

The project route also runs across numerous valleys, rivers, streams and irrigation channels. Due to the extremely undulating terrain, long bridges with high piers and diversions of streams and creeks are needed. The negative impact on the surrounding environment of these numerous structures were carefully investigated.

Through careful study of the considerations stated above, a balance of engineering safety, economy and environmental impact has been achieved. Project construction begins in mid-1988 and is anticipated to be completed in approximately four years.

2 ROUTE DESIGN AND LANDSCAPING

The proposed route was selected following careful consideration of the natural and cultural conditions of the region, such as climate, hydrology, geology, topography, mountain ridges, land use, major utilities, farmland distribution and location of communities. In addition, the route location was designed to fulfill guidelines as follows:

(a) to correspond as closely as possible with the natural terrain,
(b) to maintain the original functions of natural and artificial water systems and of existing roads,
(c) to avoid passing through areas of potential geological disaster,
(d) to achieve a targeted balance of earthwork,
(e) to minimize housing demolitions, and
(f) to coordinate with local demands and other major projects.

After thorough evaluation and comparison of all alternatives, the final route was chosen as shown in Fig. 1. It was divided into six sections based upon characters of the terrain and ecology along the route. After an evaluation of the ecological environmental impact, investigation into strategies for conservation was undertaken.

Most portions of the proposed route located in mountainous areas were designed to fringe the hillside, as shown in Fig. 2, in order to reduce excavation and to avoid excessive disturbance of the existing soil and natural ecological environment. The scenic view along the route is predominantly of rolling mountains and green plants; such a lush, attractive landscape should be appropriately preserved. Irreversible changes to the topography caused by cut and fill will be treated by planting of forestry on slopes, thus endeavoring to recreate the natural land-

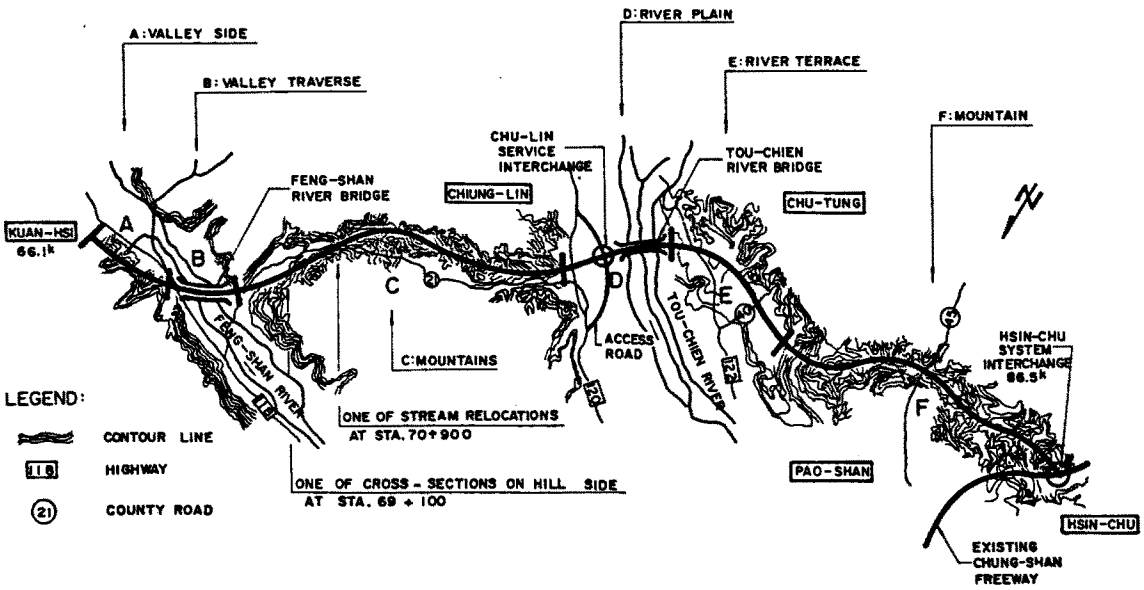

Figure 1. Layout of proposed Kuanhsi Hsinchu section Taiwan northern region second freeway

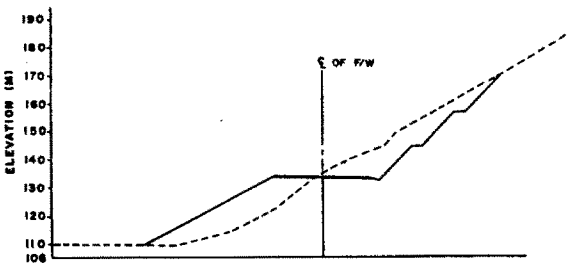

Figure 2. One of cross sections on hill side at Station 69+800

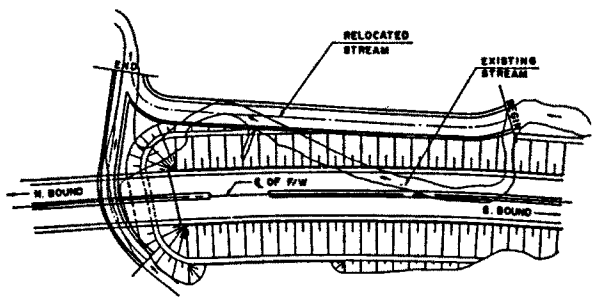

Figure 3. One of stream relocations at Station 70+900

scape. Furthermore, planting at the median and on the surface of slope protection structures will help the slopes to blend with the surrounding scenery and improve the visual feeling of the roadside atmosphere.

Due to extreme variations in topography, all bridges along the proposed road which will cross rivers, such as the Fengshan River and Tou-chien River, were designed with long spans and high piers. This will reduce the backup water height caused by erection of bridges and keep the river flow passing freely. The existing streams which intrude into the right-of-way of the proposed route were diverted according to hydraulic calculation, as shown in Fig. 3. The results after diversion and modification are that the existing streams will flow more fluently and safely than before.

The Tou-chien River plain is an open farmland whose atmosphere is quite refreshing to the drivers who are coming into this area from the prior section, which is a closed mountainous area. As the vegetation on the plain grows, the land is covered with green during seeding and sprouting, then changes to gold during the harvest season, forming a view of colorful variety. It is desirable to locate the Chiung-Lin Service Interchange on the plain, and it should accelerate development of the adjacent towns.

The plain topography will be somewhat altered due to the construction of the interchange. Therefore, in this area, special landscape design planning was undertaken as shown in Fig. 4. To distinguish the character of the interchange and form a landmark, tall trees will be planted at proper locations. To produce visual leading effects and to attract the attention of motorists in order to enhance safety, planting will be undertaken along the sides of ramps and loops to provide visual landmarks. To create an attractive scenic view, landscaping was designed to encompass formal planting within the reserved land space of the interchange. The character of the plain is maintained by the short plant species chosen for planting along the sides of the road embankment. Additionally, tree-line planting is provided at the toe of the embankment, connecting

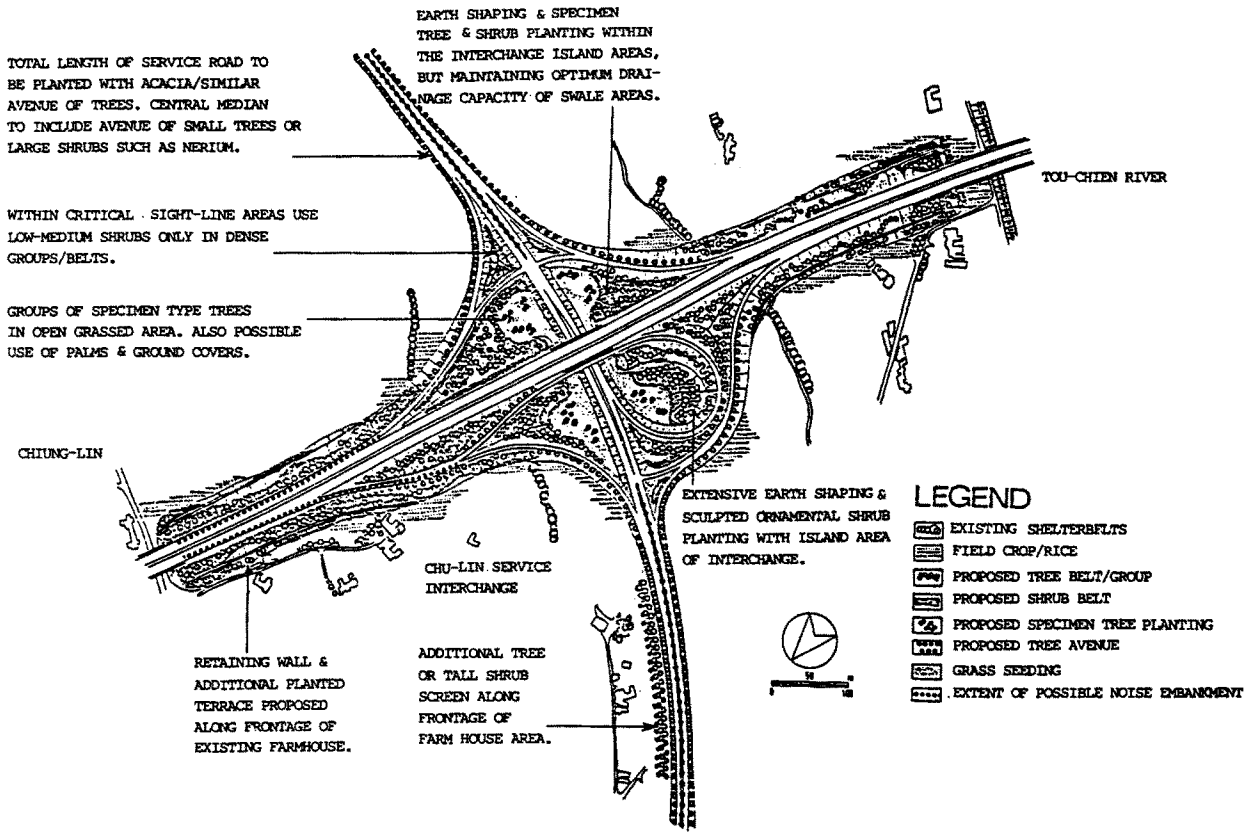

Figure 4. Landscaping plan for Chu-lin interchange

with existing field boundary windbreaks and successfully blending them with the scenery of the agricultural plain.

An irrigation canal located in Chu-tung terrace guides water from upstream of the Tou-chien River to irrigate about 65 hectares of farmland in this area. In consideration of local inhabitants who are living on farms, the proposed route maintains this Chu-tung irrigation canal to the left of the freeway. Meanwhile, in order to protect the canal's original function, the freeway will be constructed on fill in this section, thus making it convenient to connect irrigation water lines between canal branches and fields by means of box culverts underneath the freeway embankment.

The water line connection work should proceed during the intervals in farm work and be completed before the start of ploughing to avoid interrupting agricultural operation. In addition, the proposed route will be constructed on fill in the area to reduce the quantity of over-crossing flumes, to protect the original scenery of the river terrace, and to minimize excessive earth disposal difficulties. Nevertheless, as the terrace is flat and open, noise extending to the plain below could pose noise pollution problem. This could be easily adjusted by extensive planting on the slope of the embankment at the right side of the freeway.

3 ENVIRONMENTAL GEOTECHNICAL CONSIDERATIONS FOR SLOPES

As described in the previous section,the region along the route of the 20.4 km Kuanhsi-Hsinchu section of the Taiwan Second Northern Freeway is mostly hilly land with some terraces and recent alluvial plains. Deep cuts and high embankment fills are inevitable. Therefore, proper slope treatments are very important for the protection of the natural environment. During the planning and design stages, many factors, including the selection of slope stabilization, surface protection, landscaping measures, construction method, dumping of excavated earth materials, and long-term monitoring and maintenance were carefully studied. In addition to minimizing the negative impact on the natural environment due to the proposed slope works, positive beautification and improvements of the existing environment were also developed.

3.1 Avoidance of surface guniting and concrete retaining structures in slope design

All slopes along the planned route were designed to appear as natural as possible, rather than being composed of artificial, hard-featured concrete structures or gunited surfaces.

3.2 Open and symmetrical view of cut slopes

Cut slopes on both sides of the proposed new freeway were designed to be symmetrical and wide so that drivers would be afforded an enjoyable view thus creating a more comfortable,

clear and stable driving atmosphere.

3.3 Bridges versus high embankment fill

For the major traffic roads, farmland areas and major flow collection valleys through which the planned route passes, bridge design was preferred to high embankment fill as it decreases the negative impact on the environment and helps retain the natural drainage system.

3.4 Slope drainage systems

In designing the slope drainage systems, consideration was given not only to the drainage functions of the slope itself, but also to the hydrological influences of the upstream and downstream areas. Some areas originally prone to erosion will also be improved.

3.5 Protection of farmers' living environment

As the planned route passes several farmhouses, efforts were made in the design to protect the living environment of the farmers living there. These measures include the development of the earthfill noise-preventing bund or planting at the top of slopes, protection of the source, for both quantity and quality, of fresh water at the wells which farmers draw upon, and maintenance of convenient transportation between those farmers and their cultivated lands.

3.6 Potential geological disaster area improvement

The areas of potential geological disaster near the planned route will be improved in this present freeway project in order to eliminate the factors which may destroy the environment. Some potential geological disasters, such as landslide, earth debris flow, colluvium deposit, upward erosion and bank erosion existing in areas along or near the planned route, were taken into account and improved in the slope design.

3.7 Erosion resistance, landscape and special characteristics of local vegetation considered in slope protection design

Slope surfaces will be greened with the planting of vegetation. The grass and plant seeds were selected to correspond with the local vegetation environment. The location and height of plants were designed according to slope strike and dip as well as the route plan and profile to highlight the best characteristics of landscape and local vegetation.

3.8 Consideration for slope construction

Due to rapid growth in population and decreasing availability of flatlands, developemnt of slopelands becomes very popular in the ROC. However, many hill area developments have caused serious environmental pollution during the past few years due to negligence in construction control. For the new Freeway project, means for preventing pollution were considered as follows:

(1) Construction procedures for cutting and filling the slope will take into consideration the effect of local weather, geology, hydrology, and slope scale. Slope protection and drainage systems shall be effected immediately after cut or fill of each section and/or stage of a slope.

(2) Dumping areas for excess excavated earth materials were selected in a deserted valley which is located near the planned route. The areas possess both suitable capacity and independent drainage systems. The volume, source and delivery route of dumping materials and the slope of the dumping area were carefully planned and designed. Furthermore, the delivery route was principally developed to use the construction paths within the project area without using existing roads in highly populated regions. Thus, road settlement, cracks in residential buildings and environmental pollution due to earth flow will not occur during the construction of this project.

(3) Long-term slope maintenance and slope monitoring systems were developed in order to prevent any slope failure which would cause negative environmental impact. For slopes composed of special geological formation, deep cut or high embankment, monitoring systems including inclinometers and piezometers will be installed and monitored for long-term maintenance and control of the slope stability.

4 CONCLUSIONS

For the planning and design of the 20.4 km Kuanhsi to Hsinchu section of the proposed Second Northern Freeway in Taiwan, special environmental geotechnical considerations were incorporated in the project. The following summarizes the important features of the planning and design:

(1) On the basis of careful geotechnical analyses, the proposed section of the freeway was planned and designed with minimum environmental impact, least potential disastered, enforced safety protection, maximum landscaping beautification and economy.

(2) By considering the natural characteristics of the region, including topography, geology, hydrology and climate, the landscaping design not only conserves the natural environment, but also enhance the scenic view by blending the highway development into the natural environment.

(3) The planning and design utilized monitored data from instrumentation installed at strategic locations for the purpose of traffic safety and environmental protection. Data from long-term monitoring of instrumentation can be used for maintenance purposes and as reference for future planning of important projects in the region.

(4) The project establishes a model for equal emphasis on construction cost and environmental quality.