1 Impact of Motorway Construction on the Environmental Landscape and Protection Countermeasures

1.1 Impact on the natural environment

Topography

Motorways are large-scale man-made projects. During their construction, the topography of the surrounding area will be subject to significant impact. For example, before the construction of the Nanjing-Hangzhou Motorway, the area was characterized by beautiful scenery (Figure 1.1). However, since its construction, great changes have happened to the local environment. First, the motorway has occupied a large area of arable land. During Phase I of the project alone, 4329.86 mu (about 288.66 hm^2) of land and 2205.3 mu (about 147 hm^2) of excavated land was requisitioned; there was a fill volume of 6.1732 million m^3 and an excavation volume of 3.1279 million m^3. As such a large area of cultivated land was requisitioned, the topography across the construction area of the surrounding area was subject to serious degradation (Figure 1.2), especially the areas of great natural beauty. For example, over 400 000 m^3 of stone was excavated from the Donglushan Mountain in Lishui County, resulting in an 80 m high rocky slope surface (Figure 1.3). The construction of the motorway therefore resulted in heavy damage to the local environment. Of course, we can mitigate damage to the local environment by planting vegetation and covering the rock surface with plants, but it is difficult for the environment to revert back to its original condition and therefore destruction to the environment is irreversible. Data show that the area needed to construct a motorway is larger than an ordinary road or railway. In flat and hilly areas, the land occupation ratio of a motorway is usually 8.0~10.7 hm^2/km. Table 1.1 shows the land occupation of the Nanjing-Hangzhou Motorway (Phase I).

The Environment and Landscape in Motorway Design, First Edition.
Qian Guochao, Tang Shuyu, Zhao Min and Jing Chun.

Figure 1.1 Picturesque scenery before construction of the Nanjing-Hangzhou Motorway.

Figure 1.2 Excavation resulting in destruction of the landscape.

Figure 1.3 Excavation resulting in a steep slope on the Donglushan Mountain.

Table 1.1 Land occupation area of the Nanjing-Hangzhou Motorway (Phase I) (unit: mu).

Points of origin and destination	Township	Farmland	Commercial forest	Hilly land
K40+480~K50+480	Zaicheng	1063.7	118.2	23.6
K50+480~K52+300	Donglu	0	118.7	79.1
K52+300~K59+156.1	Baima	661.1	103.2	11.5
K59+156.1~K60+577.77	Gonghe	35.3	0	113.4
K60+577.77~K61+380	Shangxing	15.8	0	66.8
K61+380~K68+399.41	Jiuxian	474.4	412.4	45.8
K83+000~K99+750	Xinchang	1271.9	300.5	137
K99+750~K103+706.66	Chating	289.7	0	31.8
K103+706.66~K111+538.29	Chengnan	593	45.6	19.6
K111+538.29~K112+121.97	Yantou	42.7	3.3	1.4
K112+121.97~K116+000	Jingtang	691.3	317.7	53.0
K116+000~K122+126.5	Guijing	190.2	380.3	63.4
K122+126.54~K130+781.97	Huankeyuan	413	239.4	148.1
K130+781.97~K146+960	Dingshu	673.9	868.4	293.4
K146+960~K149+462.23	Fudong	77.7	136.4	45.3
Total		7374.7	3265.8	1168.6

1 mu is equal to ~666.67 m^2.

According to Table 1.1, the Nanjing-Hangzhou Motorway occupies an area of 11 808.4 mu (about 787.23 hm^2), most of which is farmland and commercial forest, which amounts to 10 640.5 mu (about 709.37 hm^2). As a consequence, it brought about not only a devastating effect on the local natural environment, but also had an adverse impact on local agricultural production and socio-economic development.

Soil erosion

Soil is one of the most important factors for the growth of vegetation along a motorway. During motorway construction, quarrying, borrowing earth and spoil grounds will cause soil erosion. The fertility of soil is reduced, changing its physicochemical properties, which makes it more difficult for vegetation to grow and recover. If the soil structure of the land under construction changes due to compaction from machinery or the land being trampled on, the fertility of the soil may not recover for a long time.

Soil erosion destroys the vegetation along a motorway. In turn, the loss of vegetation further exacerbates soil erosion. This vicious circle makes it very difficult for the vegetation to grow and recover. On the other hand, soil erosion causes change in topography, resulting in water and soil loss (Figure 1.4). According to a survey, water and soil loss resulting from motorway construction in Guangdong Province reaches 4.6203 million m^3 every year. For example, during the construction of the Ningxia Guyaozi – Wangquanliang Motorway, the area affected by water and soil loss increased by 592.48 hm^2. This was due to disturbing the original topography and damage to the soil

Figure 1.4 Soil erosion.

Table 1.2 Predicted value of the potential intensity of soil erosion on the Nanjing-Hangzhou Motorway (Phase I).

Section	Topography	Current situation of land		Construction period			
		Erosion modulus (t/km^2 yr)	Grade	Subgrade slope (t/km^2 yr)	Grade	Borrow area (t/km^2 yr)	Grade
K40+480~K67+920	Hilly land	1500	II	6225	IV	5505	IV
K67+920~K83+000	Flat to undulating hills	1500	II	6225	IV	5505	IV
K83+000~K95+840	Low mountains and hills	3000	III	12450	V	11010	V
K95+840~K115+205	Flat to undulating hills	1500	II	6225	IV	5505	IV
K115+205~K133+61	Low mountains and hills	3000	III	12450	V	11010	V
K133+612.5~K148+127	Flat to undulating hills	1500	II	6225	IV	5505	IV

and vegetation. Of the 592.48 hm^2 affected, cultivated land amounted to 134.20 hm^2, woodland 152.10 hm^2, grassland 295.75 hm^2, and other land 10.43 hm^2. For soil erosion on the Nanjing-Hangzhou Motorway, see Table 1.2.

According to Table 1.2, the construction of the Nanjing-Hangzhou Motorway has resulted in serious soil erosion.

Climate

Upon construction, motorways can generate a microclimate environment, which mainly depends on the properties of the underlying surface and the

composition of the atmosphere. A motorway microclimate that is adverse to plant growth has the following features:

(1) Cold. Motorways are generally far away from centres of population, with high subgrades, spacious topography and fast air convection. Particularly on interchange sections, the clearance under the bridge is relatively high, resulting in freeze injury to trees on windward slopes in North China. In the winter of 1997, one-third of Chinese Juniper in the central reservation died or was affected by frostbite due to the wind beside the approach of Shahe Grand Bridge 233 km along the Beijing – Shijiazhuang Motorway.
(2) High temperature. At either side of the central reservation, there is a 10-m-wide black paved surface. During the summer, the air temperature can reach roughly 40°C, but after factoring in the thermal radiation of the black pavement, the local air temperature may reach over 50°C in some areas.
(3) Drought. Due to the thermal radiation of the black pavement, the high temperature exacerbates the evaporation of soil moisture and the transpiration of trees, resulting in the death of trees due to drought. This phenomenon is even more apparent in the central reservation.
(4) Strong gale. Motorways feature high subgrades, spacious topography and fast convection. High-speed vehicles increase the wind speed, especially large buses, which may produce an instantaneous wind speed of 25 m/s. This is a very common occurrence, which causes the trees to sway wildly, resulting in damage to their root systems and exacerbation of water loss and drought.

Hydrology

In motorway construction the direction of surface water may often change its course. Due to the diversion of the river flow, water and soil loss worsens at areas where the flow of water is concentrated and erosion occurs where the structure of the water flow is adverse. In river or wetland areas, it is necessary to change the original direction of the river when a motorway is built. After the direction of the river has been changed, a very large flow is generated in areas where many waterways come together and the flow rate speeds up. The hydrological conditions then change, resulting in floods, a worsening of water and soil loss or an increase of downstream silt (Figures 1.5 and 1.6). The area where the Nanjing-Hangzhou Motorway (Phase I) was built is in the Qinhuai River basin. Along the route, there are low mountains, hills and flat areas as well as numerous big and small lakes and crisscrossing rivers. Most of the waterways that the Nanjing-Hangzhou Motorway passes over are barge routes and irrigation channels. Although the aim was to minimize and avoid adverse effects during bridgework, culvert design and subgrade construction, elements

Figure 1.5 The motorway results in the redirection of the original waterway.

Figure 1.6 Water and soil loss due to the destruction of vegetation.

including the navigation, irrigation and drainage of the existing waterways were still damaged or impaired.

Vegetation

The impact of a motorway on vegetation mainly refers to the direct impact of land destruction, borrowing earth and spoil grounds during motorway construction, as well as the indirect impact of motorway traffic. The former is transient and irreversible; the latter is more long-term and reversible. During motorway construction, direct destruction of vegetation mainly stems from the following two aspects: permanent destruction from site clearing, and damage from the temporary spoil ground and construction road. For example, the land permanently occupied by the Jilin–Changchun Motorway project is 571.8 hm^2, of which dry farmland accounts for 76.5%,

paddy fields 12%, uncultivated land 1.9% and woodland 9.6% (19 360 timber trees were felled). According to calculations, the amount of carbon dioxide absorbed annually by the vegetation has decreased by 8274 t and the amount of oxygen released annually has decreased by 6040 t. Due to the occupation of cultivated land, the amount of oxygen released annually has decreased by 1500 – 5000 t. Using Zhoukou – Shengjie (Provincial Boundary) Motorway in Henan as an example, the 9.498-km-long section within Beijiao Township, Shenqiu County alone covers a cultivated land area of 69.8 hm^2, equal to a vegetation damage rate of 1.968%. As a large amount of cultivated land has been occupied, farmers may cut down woodland to make up for the occupied land, further worsening the damage to the vegetation along the motorway (Figure 1.7). After the completed motorway was opened to traffic, pollution from vehicles has also been an indirect factor contributing to vegetation damage. It is reported that farmland within a range of 50 m of both sides of the motorway has seen an average reduction in output of 15% due to dust and exhaust fumes from trucks transporting coal from Shanxi Province to other regions. As a result, the wheat yield in the province has decreased by 28.13 million kg every year, equal to a loss of RMB 33.75 million.

Of the land requisitioned for the Nanjing-Hangzhou Motorway (Phase I), arable land amounts to 150.02 hm^2, commercial forest 50.17 hm^2, hilly land 22.68 hm^2, borrowed land 147.02 hm^2, as well as extra temporary land use for the construction road, mixing yard, prefabrication yard and construction camp. The vegetation at these places was cleared during construction. After completion of the project, new vegetation was planted over an area of 909 029 m^2, accounting for 20.76% (6535.16 mu or ~436 hm^2) of the total land requisitioned. In other words, the Nanjing-Hangzhou Motorway (Phase I) resulted in a loss of green vegetation of 271.90 hm^2 (Figure 1.8) to this area; it was therefore inevitable that the local environment would be affected.

Figure 1.7 The motorway occupies the local tea plantations and woods.

Figure 1.8 Forest vegetation in the Donglushan Mountain.

Wildlife

Wild animals are the main victims of habitat fragmentation during motorway construction. As the forest decreases in size and is divided by residential areas and traffic networks, their habitat gradually shrinks. These small habitats are not sufficient for the animals to survive. If their territory is too small, they cannot acquire enough food, resulting in the decline or extinction of these animal populations. Increased traffic flow and expanding human activity also reduces their habitats, affecting their mating and reproduction, further aggravating the impact on them. In addition, newly built motorways directly cause a loss of habitat and terrain features, resulting in a change in climatic factors such as sunlight, wind speed, temperature and humidity. Meanwhile, vibration, noise, atmospheric pollution and soil pollution from vehicles has a negative impact on the survival, reproduction and migration of local plants and animals.

According to a survey, there are fewer wild animals and species in areas next to the Nanjing-Hangzhou Motorway (Phase I), including species such as wolf, boar, vole, hedgehog, yellow weasel, rabbit and common birds. Although the construction of the motorway has resulted in adverse impacts on such wildlife, the consequences are not too severe as there are no rare or state-protected species in the region.

1.2 Impact on history, culture and scenery

If the route is not selected carefully or if no attention is paid to conserving water and soil during construction, there may be the following problems:

(1) The motorway passes through a town.
(2) It passes through a scenic spot.

(3) It goes through a forest.
(4) Mountains have to be cut into and deep holes must be filled.
(5) The flow of the river changes and streams become blocked.

Poor route selections such as these not only damage the ecological environment across the region but also the integrity of the history, culture and scenery in the area, as well as the regional tourism resources. A survey has found that there are no cultural relics and scenic spots requiring special protection along the Nanjing-Hangzhou Motorway (Phase I), so the impact on the history, culture and scenery of the area along the motorway has been small and the prospect for the development of tourism resources is promising. Phase II passes by the Longbeishan Mountain National Forest Park but does not go directly through it, so its impact is negligible. The completed Nanjing-Hangzhou Motorway serves as a protective barrier for the Longbeishan Mountain National Forest Park, protecting it against the erosion of land for urban development.

1.3 Pollution of the surrounding environment

Motorway construction has polluted regions along the route to a different degree.

Noise pollution

There are two kinds of noise pollution: one is from excavators, bulldozers, land levellers, lorry mounted mixers and other types of construction vehicles. These vehicles and equipment create significant noise pollution. For example, the noise from a common road building machine exceeds 80 dB, while that from a pile driver is higher than 100 dB. The other kind of noise pollution is from traffic, forming a noise belt along the motorway route. The noise from these sources has a negative psychological and physiological impact on constructors and people in the surrounding areas. It also reduces people's work efficiency, having a particularly apparent impact on sensitive areas with a high population density on both sides of the motorway (schools, residential areas, commercial districts, hospitals, etc.). At nighttime, the noise affects the lives of people living alongside the motorway and the impact will only worsen in the future (Figure 1.9).

Water pollution

There are two sources of water pollution from the motorway: one is from subsidiary facilities along the route, such as service areas, toll stations, management centres and maintenance work zones. In general, a motorway can produce about 200 000 t of sewage a year. After treatment, the sewage can

Figure 1.9 Residents on both sides of the motorway will be disturbed by noise.

Table 1.3 Predicted value of the concentration of pollutants in the surface runoff.

Item	SS	BOD5	Petroleum	CODcr
120 min mean value (mg/l)	100	5.08	11.25	107
Quantity of pollutants discharged (t/a)	2977.8	15.1	33.5	318.6

meet effluent standards, that is CODcr 100 mg/l, BOD 530 mg/l, SS 70 mg/l and petroleum 10 mg/l. However, this waste water will result in water pollution if discharged into a river or a lake. If the waste water is not treated or if treatment is not complete or does not meet the necessary standards, the resulting water pollution is more severe and harmful.

The other source of water pollution is pollutants from automobile exhaust fumes, surface residues and surface materials. These pollutants flow across the surface of the road into reservoirs and rivers after rain, contaminating these areas to a certain degree. In the region where the Nanjing-Hangzhou Motorway (Phase I) is located, the mean annual precipitation is 1050 mm, and the total area of pavement is 2.836 km^2, therefore the annual surface runoff volume is 2 977 800 m^3; the total discharged quantities of all types of pollutants are shown in Table 1.3.

Atmospheric pollution

The main cause of air pollution is automobile exhaust emissions, including carbon monoxide (CO), nitric oxide (NOx), total hydrocarbons (THC) and total suspended particulates (TSP), of which NOx is the most serious pollution to the environment, followed by CO and THC.

After the Nanjing-Hangzhou Motorway was completed there was an increase in NOx emissions because vehicles started to travel much faster. The motorway does not pass through urban areas, thereby reducing congestion on urban roads and relieving air pollution of cities along the motorway.

Figure 1.10 The storage yard is a source of on-site dust pollution.

Dust and waste

Dust from construction sites, storage yards, uncompleted pavement and construction side roads results in serious pollution of the surrounding environment. Relevant testing shows that the concentration of TSP is 5.097 mg/m^3 150 m downwind of a construction vehicle, higher than the national ambient air quality Grade II. As the wind speed increases, the area affected by dust becomes larger (Figure 1.10).

The household refuse and construction waste produced by construction workers has a negative impact on the surrounding environment, such as visual pollution and damage to the beautiful surroundings and vegetation. Examples include large quantities of building materials and other materials abandoned during transportation, stones and earth left behind after demolition work, household refuse and construction waste from construction camps, refuse from service areas, parking areas and management centres as well as litter dropped by drivers and passengers. This litter is mainly waste paper, plastic bags, plastic boxes and plastic bottles. As the number of vehicles increases in the future, pollution from litter will become more severe.

1.4 Impact on public activities and production

Because the Nanjing-Hangzhou Motorway is totally enclosed with a complete interchange system, it separates villages near the route. The Nanjing-Hangzhou Motorway (Phase I) passes directly through 5 villages and there are 9 villages about 15 – 100 m away from its main central line. The separation that the motorway causes results in inconvenience and difficulties for farmers working in the fields and moving from one area to another, as well affecting administrative divisions and regional planning (Figure 1.11). After land has been occupied by the motorway, some farmers lose their land

Figure 1.11 The motorway isolates the village on both sides.

and therefore have less income, resulting in a loss to the regional economy. Meanwhile, the resettlement and relocation of residents due to the project seriously affects farmers' everyday lives and is an added psychological burden.

1.5 Landscape protection countermeasures and measures

In order to prevent and alleviate the damage and adverse impact on the surrounding region during construction, it is important to focus on two stages of the project: planning and operating. Various measures should be taken to solve problems in design, construction and operation. Special countermeasures should be introduced for environmental protection, foreseeing hidden dangers and taking measures to eliminate them. All measures should be adopted in order to solve unavoidable problems that damage the environment. With regard to adverse impacts that have already occurred, measures should be taken to remedy and correct them. There are four specific measures that can be taken.

Select a rational route and minimize damage to the environment

Use new technologies to optimize the design

Selecting and determining a good motorway route design is a prerequisite for building a good motorway. First, it is necessary to investigate and survey the natural and social environment of the regions concerned, and carry out a detailed analysis on the data in order to determine an optimal plan. 3S technology for survey and design can not only enhance survey precision, but also can lower the survey cost, ensuring the most optimal motorway route selection. 3S technology refers to the integration of remote sensing technology (RS), the geographic information system (GIS) and the global positioning

system (GPS), which can better simulate the hydrological, geographical, geological and climatic conditions of the regions where the motorway would pass through, thereby selecting an optimal motorway route.

Bypassing urban areas to coordinate with urban planning

When selecting a motorway route, it is best to bypass towns, natural conservation areas, water conservation districts, scenic spots, historical sites and tourist attractions, in order to prevent or mitigate the motorway's impact on the environment (Figure 1.12). The route selected should avoid interfering with the development of towns and help drive their further economic development. For this reason the distance between the motorways and towns should be chosen appropriately. The distance between the Nanjing-Hangzhou Motorway and Lishui, Liyang and Yixing is about 1, 1.5 and 2 km, respectively, therefore avoiding interfering with the urban planning of these three regions. Meanwhile, the route stays away from large-scale infrastructure and agricultural centres of excellence located in some cities.

Reduce land occupation and protect agriculture

Land occupied for motorway construction is permanent, therefore, the occupation of arable land should be minimized during planning, especially high-yield plots and commercial crop areas. More earth should be borrowed from barren hills in order to save arable land. As shown in Figure 1.13, no borrow pit is excavated next to the Nanjing-Hangzhou Motorway in the Taihu Lake region in order to protect precious farmland resources there. In order to save land, the central reservation of the 2 km connecting section between the Nanjing – Gaochun Motorway and the Nanjing-Hangzhou Motorway is of narrow design, being only 2 m wide.

Figure 1.12 The motorway keeps away from the ancient pagoda in Yixing and passes by Longbeishan Mountain National Forest Park.

Figure 1.13 The central reservation between Luojiabian and the toll station on the main lane is 2 m wide.

Reduce the amount of excavation and fill to conserve natural vegetation

The motorway alignment should integrate fully with the local topography. As long as the requirements for motorway standards are met, the alignment should adapt to topographical changes as far as possible, integrate with the natural environment and ensure the reduction of the amount of fill and excavation in order to alleviate damage to the original land vegetation. For example, a tunnel was built through the Tizishan Mountain so as to reduce the impact of the Nanjing-Hangzhou Motorway on the natural mountains in the Taihu Lake scenic area, thereby conserving the natural environment (Figure 1.14). Shilibei Village, 5 km north of Lishui County town, Nanjing, intersects with the Changzhou – Liyang Motorway, where there is an ancient Ginkgo bilobamaidenhair tree within the planning boundary line. According to legend, this ancient tree was planted in the Ming Dynasty (1368-1644 AD).

Figure 1.14 The tunnel in Tizishan reduces damage to the natural environment.

Figure 1.15 Motorway geometric design is adapted to topographical changes.

In order to protect it, the villagers were willing to dismantle more houses. After repeated research, the construction headquarters decided to alter the design scheme – changing the cut slope into a vertical type retaining wall. In other countries, people pay more attention to the adaption of the motorway to the local topography when selecting motorway alignment. Sometimes the two sides of the motorway are not at the same height (Figure 1.15), thereby reducing the excavation of earth and rock and minimizing the impact on the surrounding environment. Motorways should be integrated into the natural and social environment as far as possible.

Design passageways to resolve isolation issues

Motorways are in general enclosed networks, and this will unavoidably result in inconvenience to the lives and agricultural production of residents nearby, as well as isolating the habitats of wildlife populations. For this reason all kinds of passageways should be considered during design. The Nanjing-Hangzhou Motorway (Phase I) is constructed with 54 passageways, 102 culverts and 8 overpasses for tractors and people, which essentially meet the production and daily needs of people living along the route as well as ensuring sufficient habitat for wild animals (Figure 1.16).

Attach importance to environmental protection projects during construction, alleviate pollution and prevent water and soil loss

Rational use of land resources

During motorway construction, the construction procedures should be determined first. Temporary land occupation should be minimized, the occupation time should be shortened and the land should promptly be restored to its

(a)

(b)

(c)

Figure 1.16 (a) Overpass, (b) passageway and (c) culvert.

original function. With regard to temporary land use for stock grounds and mixing yards, land within the scope of the motorway should be selected, such as interchanges, service areas and toll stations, so as to ensure that additional land is not occupied. If conditions permit, the bridge construction site may be arranged at the intersection or on the banks of the river. Temporarily occupied farmland should revert back to farmland immediately after construction.

Prevent water and soil loss

During motorway construction, a huge amount of excavation take place, such as subgrade, retaining wall and slope protection works. With regard to the area where there may be direct surface runoff during rain, the sedimentation basin and geotextile fence should be constructed in advance to prevent water and soil loss. Thus in the case that muddy water flows through the sedimentation basin slowly, silt will be deposited. All the engineering works for soil conservation, soil consolidation and preventing water and soil loss throughout the motorway should be carried out simultaneously with the main works and subject to handover and acceptance. The Nanjing-Hangzhou Motorway project was an innovative model in slope protection technology. The gradient of the side slope is reduced as far as possible, to a maximum of over 1:6. The hard side slope constructed with mortar rubble was changed to a soft soil slope for ecological protection, thereby expanding the landscaping and vegetation area. As such, spoil and rock were used as subgrade fill. The rock disposal dump site was used for landscaping. For example, a sightseeing pavilion was built at the rock disposal dump in Donglushan after being refilled with earth, greatly improving the surrounding environment (Figures 1.17 and 1.18). During construction along the waterways or when constructing bridge foundations, spoil and other waste are not allowed to be dumped into rivers, lakes, reservoirs or irrigation canals in order to protect water sources and waterways. In addition,

Figure 1.17 The stone is filled with earth for greening.

Figure 1.18 A pile of rocks becomes a scenic spot.

the subgrade and the surface drainage system should not destroy the original river system and surface runoff mechanism.

Prevent and control pollution

During construction the main sources of environmental pollution include noise and dust. The noise stems from construction machinery and transportation vehicles. Noise should be strictly controlled in accordance with the *Noise Standards on Both Sides of Arterial Traffic*, and *Noise Limits for Construction Sites*, to reduce noise as far as possible. Measures generally taken to reduce noise are to emphasize safe and civilized production and strengthen the management of construction machinery and transport vehicles to ensure that noise from construction machinery conforms to the limits. Other countermeasures include adjusting construction and operation times, avoiding construction during the night, concentrating the operation of noisy machinery within a certain time, completing construction as soon as possible, preventing noise pollution from blasting, adjusting the quantity of construction machinery in operation and compensating those who suffer from noise.

Dust causes air pollution during construction. A wind shield wall (net) should therefore be erected around the material store yard, and especially around the fly ash pile. The road to the store yard should be sprayed with water frequently; the bituminous mixture should be batched and mixed in a fully enclosed yard or station. The subgrade, should be compacted layer by layer, reducing dust by spraying with water and therefore ensuring that the water quality on both sides of the road is not affected by the dust and rainfall runoff. The bituminous mixing yard should be located downwind of the prevailing wind direction and at least 300 m away from any villages, towns or residential areas in order to prevent pollution from bituminous fumes.

Figure 1.19 The ground is afforested immediately.

Promptly and comprehensively plant vegetation to prevent water and soil loss and pollution

When construction is complete, clear up and level the ground immediately, then plant nursery-grown plants and grass according to the design requirements. These are effective measures to prevent water and soil loss, surface water pollution and the inhalation of harmful gases as well as to prevent dust and reduce noise (Figure 1.19). Land vegetation helps to mitigate the flow of rainwater to the surface soil and slow down the runoff, as well as enhance sedimentation efficiency, filtrate suspended solids, and improve soil permeability. As a result, soil erosion resulting from surface runoff is alleviated and runoff pollution can be checked effectively. As plants develop roots and continue to grow, their ability to conserve water and prevent and control pollution increases (Figure 1.20).

Strengthen environmental quality management during the operation period

Refuse and water from service areas should be treated with suitable waste and sewage treatment equipment based on the amount discharged before being discharged according to required standards. This prevents waterways from being polluted. For example, the sewage treatment facilities in the Tianmu Lake service area uses an advanced recycled water treatment system, and the discharged water meets the grade one standard; if it is filtered and disinfected further, it may be used for purposes such as watering flowers, washing cars and flushing toilets. In order to prevent noise from affecting residents along the motorway, measures against noise should be employed, such as

Figure 1.20 The scenery of the Donglushan Mountain with grass and trees after destruction.

providing a forest belt between the village and the motorway, heightening the fence, installing anti-noise windows and erecting noise barriers. Although the soundproof effect of a forest belt is not as good as other engineering measures, and despite that fact that a large area of land is required, forest belts can afforest and improve the surrounding environment in addition to reducing noise, and conserving water and soil. They help to restore the local ecological environment and make the environment more pleasant for people to live in. Forest belts are therefore often employed as a preferred way to reduce noise.

In the period of motorway operation, air quality on both sides of the route declines due to pollution from automobile exhaust fumes. The main pollutants include CO, NO_2 and THC. By monitoring the air quality in these regions, it has been observed that among the pollutants, 65 – 80% of CO, 50 – 60% of NO_2 and 80 – 90% of THC come from automobile exhaust emissions. It is therefore crucial to improve air quality along the motorway by reducing emissions from automobile exhausts. At present, the most effective ways to reduce emissions from automobile exhausts include improving operation and engine performance, modifying the fuel used and treating automobile exhaust fumes.

Restore and create natural landscapes by planting vegetation, enabling the motorway to integrate with the surrounding environment and promote the development of tourism

Great efforts should be made to design the landscape of the whole motorway project. By planting vegetation to improve the landscape, the construction of the motorway will ensure the integration of local landscape, environmental protection and tourism. A good environmental design not only improves

the natural environment along the route, it also enriches the landscape and fully maximizes the potential for tourism in the region, while eliminating or alleviating driver fatigue and greatly reducing traffic accidents. The following actions should therefore be taken.

Plant vegetation in all the exposed areas and restore the surrounding ecological environment to its original state

All the exposed areas within the separation fence should be planted with trees, flowers and grass, especially with native tree and grass species. The structural features of the natural plant community should be simulated as far as possible to eliminate the adverse impact of construction on vegetation and the environment along the motorway as well as to lessen the degree of damage. For this purpose, within the 31-km-full length of the Nanjing-Hangzhou Motorway (Phase I), the afforested area amounts to more than 900 000 m^2. Large scale greening of the road area is also a positive measure to conserve water and soil and improve the surrounding environment.

Build themed landscapes

Motorway landscapes should be both integrated into the natural environment and visually appealing. For example, many attractive natural landscapes have been created within the interchange area and sensitive zones along the motorway. By planting large areas of tall trees and shrubs, redirecting water and rearranging rocks, many landscapes such as woodlands, grasslands, fields and wetlands have been created. These man-made landscapes fit seamlessly into the natural environment and highlight local cultural characteristics, forming a more attractive landscape for visitors.

Use ecological protection technology to cover rocky slopes with vegetation and restore the damaged ecological environment to its original state

With respect to large areas of cut rock and side slopes, a series of new technologies and methods should be employed for restoration as it is difficult to restore vegetation. Examples of this new technology include 'soil replacement and sowing', 'soil consolidation with straw bags' and 'soil consolidation with straw sticks'. Through such new technologies and methods, green vegetation covers the rocky slopes again, which successfully blends into the surrounding vegetation, thereby improving and enhancing the quality of the local environment and landscape.