



Landscape design of mountain highway tunnel portals in China

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ABSTRACT

Landscape design of tunnel portals has been under intensive study in recent years. This paper summarizes the general development of highway tunnels and the main problems concerning highway tunnel entrances during this development phase in China. It then analyzes the significance of mountain highway tunnel landscape design in terms of preventing travel fatigue, visual adaptation, communicating and displaying culture, land marking, and environmental protection. Thirdly, it lays down the principles for landscape design, e.g. safety, failure prevention, physiological, anthropological, blending and economic principles. Lastly, it discusses the diversity of landscape designs in China, including types of tunnel portals, integration with local cultures (subdivided into ethnological culture, regional culture and historical culture), environmental protection awareness, lighting transitions in tunnel entrances, blending with the surrounding environment, symbolic and metaphorical skills in tunnel portal landscape design, and special decorations. The results suggest that landscape design of tunnel portals is a comprehensive artistic endeavor, involving local culture; bionics; psychology; environment protection; lighting; structural techniques; new material implementation; and new technical arts. In conclusion, good landscape design requires intensive and collaborative interdisciplinary studies.

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1. Introduction

Worldwide, tunnel entrance construction presents challenges because:

- (1) The cover depth at the tunnel entrance is shallow as it often moves through a mountain surface layer whose rocks are usually broken and seriously weathered. So, the surrounding rocks at a tunnel entrance have poor stability and have no arching strength.
- (2) Tunnel entrance excavation destroys the balance and the stability of the original slope, easily leading to landslides or collapses.
- (3) The unsymmetrical loading at a tunnel entrance is formed when a tunnel obliquely passes through a mountain or some rock layers, which will cause bigger bending moments and stresses in the supporting structure and bring potential danger.

The outside framework of a tunnel portal possesses several functions. It primarily acts as a structural support against earth pressure and may stabilize surrounding rocks as well as prevent

the adjacent road area from rockfall and avalanche damage. Secondly, it buffers brightness differences between the inside and outside of the tunnel, providing a lighting transition for visual safety and driving comfort. Thirdly, the tunnel portal may serve as a landscape element which can harmonize the tunnel with the surrounding environment. In addition, surface water can be diverted above the tunnel portal at the same time.

In China, before the 1990s, a winding mountain road or path was almost the only choice for crossing mountainous areas and tunnels were rarely used. This was because of the economic situation, technological level and classification grade factors. So, the question of tunnel portal landscape design did not arise. Along with the rapid development of the Chinese economy and the increasing investment in construction of infrastructure facilities in recent years, mountain highways have been developing quickly all over the country. As a result, tunnels are widely employed today in traversing mountains.

Peila and Pelizza (2002) argued that "the architectural and landscape aspects related to tunnel portals become very important as the awareness of environment protection by designers gives rise to elevated concerns of integrating an infrastructure with its surroundings". In China, attention has been increasingly accorded to the landscape function of tunnel portals (Guan, 2004; Lin, 2007; Li, 2008; Wu, 2008; Ye et al., 2009). As a result, landscape design of tunnel portals has become a focus and a variety of highway tunnel portals have been built recently. Portals are not only utilized as

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tunnel entrances, but also regarded as places for demonstrating regional cultural and esthetic accomplishments. Hence, landscape architecture in connection with tunnel portal design has become connected to the social interests of the region.

This paper mainly discusses several issues in relation to tunnel portal landscape design and highlights some exemplary portals for highway tunnels designed recently in China.

2. The general development situation of Chinese highway tunnels

In the last decade, with the rapid development of mountain highways, tunnel construction has become the first choice for highway alignment because of its advantages for optimal alignment, shortening mileage, saving traveling time and enhancing operation efficiency. In fact, China has already become the country with the most highway tunnels and the longest highway tunnel mileages (Li, 2008). Fig. 1 shows the general development situation in terms of the number of highway tunnels and their length in China in recent years.

3. Main problems of highway tunnel entrance engineering in early periods in China

3.1. Unreasonable tunnel portal position

Generally speaking, a tunnel often enters a mountain at a ridge or near a ridge position due to the following advantages: (1) there

is a good geological condition at the mountain ridge with only a shallow accumulation of loose materials; (2) the slope is gentle at the mountain ridge, which is good for slope stability; (3) drainage is convenient around the tunnel portal.

But highway tunnels often enter a mountain through a valley in practical tunnel engineering due to general route planning or economic considerations. This kind of tunnel portal not only brings negative effects on slope stability, but also causes surface water within the valley to flow into the tunnel portal, thus increasing the difficulty of portal drainage (shown in Figs. 2 and 3).

3.2. Deep and wide excavations were often used in tunnel portal engineering

For a long time, deep and wide excavations were often used in tunnel portal engineering because of construction cost advantages (see Fig. 4). In this case, the ground was often stripped as much as necessary and concrete supporting walls remained a dominant visual feature. Also, a slope supporting wall was frequently used for enhanced stability of slopes in the neighborhood of tunnel portals (see Fig. 5).

At the same time, the deep and wide excavation can destroy the intrinsic equilibrium state and the stability of the original slope, and lead to an increased landslide or collapse potential. Furthermore, this excavation severely damages the natural environment and the volume of ground to be removed from the site.

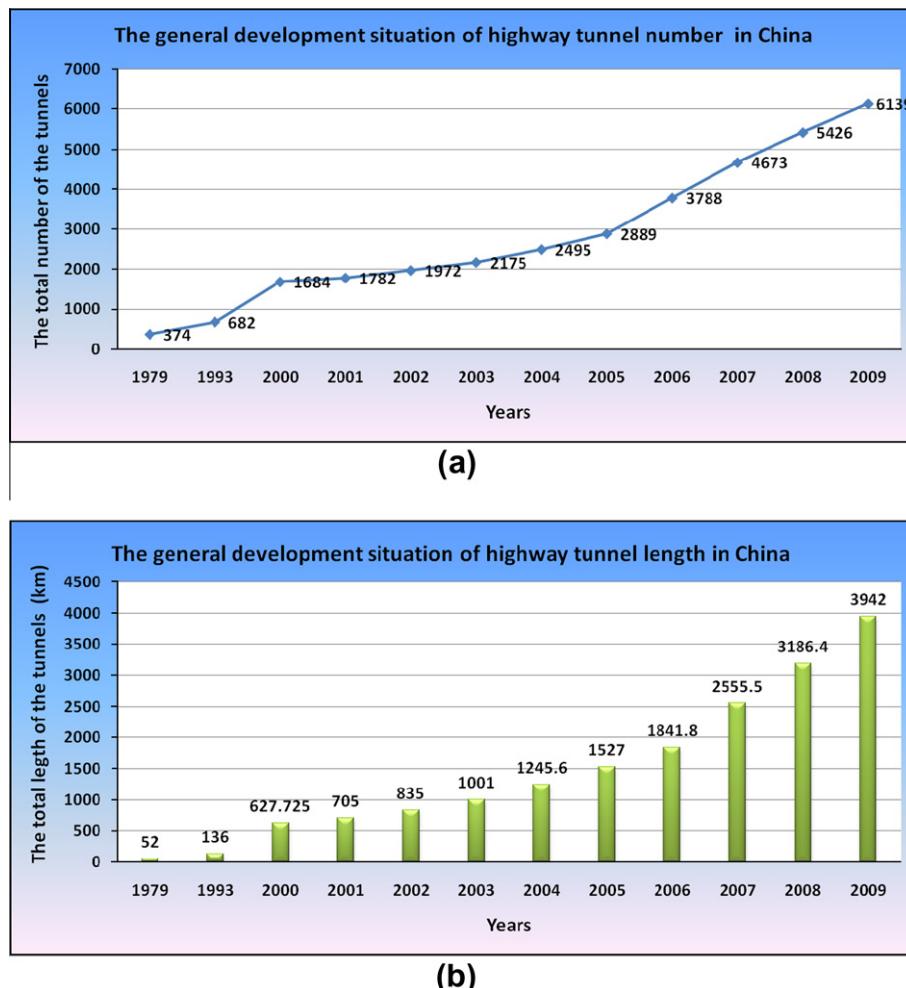


Fig. 1. The general development situation of the total highway tunnel numbers and length in China.



Fig. 2. The highway tunnel portal located in mountain valley.



Fig. 3. The surface water near the valley flow to the tunnel portal.

3.3. The portal structure is massive, stiff and inanimate

In traditional design approaches, the tunnel portal was exclusively considered as a supporting structure against earth pressure and was used to stabilize surrounding rocks as well as prevent the neighboring road from rockfall and avalanche damage. Therefore, a large number of massive portals, such as the end wall tunnel portals and wing wall tunnel portals, were widely developed at highway tunnels (see Fig. 5). Usually, the difference among these



(a)



(b)

Fig. 4. Deep and wide excavations for tunnel portals.

tunnel portals was principally in the sizes and inclinations of the end wall or the wing walls. And the structures often were built using stone blocks or concrete, which looked gray and dull and gave a tedious feeling to drivers and passengers.

As a whole, the massive portal structure not only changed the portal environment but could compromise slope stability and affect the local landscape in the vicinity of the portals.

3.4. Serious environmental destruction and distinctive man-made impression

In traditional methods of tunnel entrance construction, the portal structure extends around the tunnel entrance for a certain distance and then, for preventing landslides and collapse, the slope is often covered by shotcrete or by grouting a rubble slope (see Fig. 6). This not only destroys the natural environment and leaves a distinct man-made mark, but also causes aging and weathering problems over time. Moreover, the shotcrete or grouting of the rubble slope prevents the original vegetation from recovering, and this leaves the slope naked and with long-lasting ecological damage (shown in Fig. 6).

In general, as described above, the tunnel portal was exclusively considered as a defensive construction, so, the mechanical stability of the portal structure was the chief question, and hence the ecology, environment, esthetics or landscape were not even considered in the traditional tunneling approach.

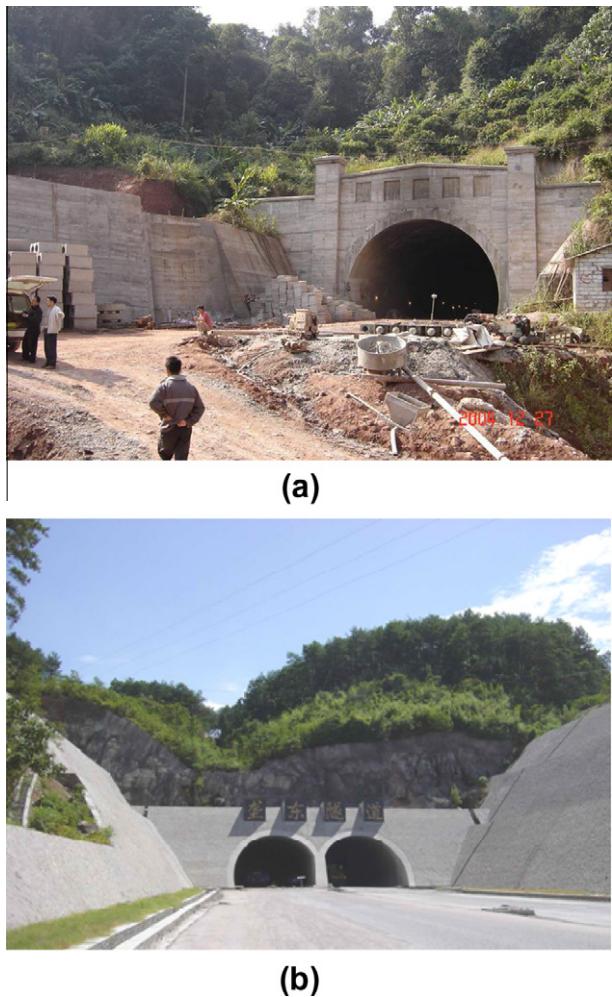


Fig. 5. The massive tunnel portals of defensive type.



Fig. 6. The naked shotcrete covering slope of tunnel portal.

4. The impacts of landscape design of mountain highway tunnel portals on users

4.1. Preventing travel fatigue

Drivers can easily become fatigued when driving long distances on highways and the passengers easily become bored after a long journey. In this regard, a good tunnel portal landscape can be a point of interest and relief for drivers and passengers as the grace-

ful scenery near the tunnel entrance can have a great visual impact. In the same way, a good tunnel portal expressing cultural connotations can add to the interest level of the journey through a particular region.

4.2. Lighting transition and visual adaptation

It is well known that there are lighting transition problems when vehicles pass into and out of a tunnel in daytime. A good tunnel portal landscape is good for visual adaptation by providing a gradual light transition at the tunnel portal, thus being good for safe driving.

4.3. Communicating and displaying culture

Besides its transportation function, the highway is a window for displaying local culture. Chinese culture has a long history and many unique features and highway design can be extended to reflect such cultural aspects. The scenery and the folklore in a region can be communicated to drivers and passengers by a variety of information elements along the highway with tunnel portals providing a special opportunity to display cultural connotations.

4.4. Providing local landmarks

Many Chinese provinces and cities have unique or widely appreciated features that serve as an identification for the area. For example, Hainan is known for its beautiful beaches. Yunnan is famous for its stone forests and as the home of 26 different ethnic groups. In fact, tunnels are often named according to the nearby places or special landscape features. Therefore, people are accustomed to regarding tunnel portals as reference landmarks for mountains, rivers, historic spots, stockaded villages or scenic spots.

The tunnel name and other cultural symbols associated with the local feature on a tunnel portal form an integrated landmark, which is unmatched by any other ordinary signage on the highway—with the potential to leave a deep impression on drivers and passengers.

4.5. Environmental protection

As mentioned previously, the traditional tunnel entrance slope is often stabilized by covering with shotcrete or by grouting a rubble slope. This destroys the natural environment and leaves lasting ecological damage. The new ecological tunnel portal landscape concept pays much more attention to maintaining and restoring slope vegetation, which not only stabilizes the side and facing slopes through the development of the plant root systems, but also reduces soil erosion and runoff and contributes to low environmental impact from the tunnel portal.

5. The principles of landscape design of mountain highway tunnel portals

As distinct from artistic decoration, the highway tunnel portal landscape is a comprehensive engineering and artistic endeavor, which combines landscape architecture, architecture, horticulture, lighting control technologies, geotechnical engineering and structural engineering into an integrated design.

Its primary task is to fulfill the transportation function, however, its overall long-term success is dependent on dealing effectively with the many varied design aspects described above. The principles for landscape design of mountain highway tunnel portals are summarized as follows.

5.1. Safety principle

Safety issues should never be treated lightly. No parts of the tunnel portal landscape should bring adverse effects to the transportation function of the highway. So, the tunnel portal landscape should provide passengers the delight of the journey on one hand, and should not divert the drivers' attention and affect the driving safety because of a colorful or busy background on the other hand.

5.2. Minimal impact principle

The minimal impact principle indicates that the best protection is to disturb the existing natural environment as little as possible (as little destruction to the existing natural environment as possible in the construction of the tunnel portal). The existing vegetation is difficult to recover after it is destroyed and, in most cases, the existing environment in a mountain has stabilized after a long geological time. Therefore, maximum protection to the environment, minimal damage and maximum restoration are critical aspects for good tunnel portal landscape design and construction. In addition, the design should actively protect and save natural resources, such as land, water and biological resources and provide an example to encourage others to take care of nature, ecology and environment in the area.

5.3. Physiological principle

The earlier part of this paper has mentioned that drivers can easily become tired when driving on a highway and that passengers become bored after a long journey. Also, the long distances and brightness variations aggravate fatigue as vehicles pass in and out from tunnels frequently.

Consequently, we propose the physiological principle in highway tunnel portal design, which can reduce monotony by using artistry in design and interesting variations in tunnel portals. Humanizing the landscape of highway tunnel portals can provide interest to drivers and passengers and increase the pleasure of the driving experience.

5.4. Regionalism principle

Tunnels may be located in a variety of different geographical areas and have different landscapes, climates and environments. People living different regions have diverse regional cultures, folk traditions, and esthetic preferences. These elements all need to be taken into account for the construction of highway and highway tunnels.

The regionalism principle in this paper means integrating a tunnel portal landscape with local features, such as the regional cultures, local natural environment, local folk traditions and esthetic preferences, so that the tunnel portals can bring honor to the local culture and leave a deep impression on passengers through this special expression.

5.5. Blending principle

The blending principle requires the tunnel portal landscape design to fit local conditions and blend into the surrounding environment. In this regard, the portal landscape can correspond with the classical concept of a Chinese garden—"even though it is man-made, it seems to be natural".

A more precise meaning of the blending principle in tunnel portal landscape design comprises three aspects:

- (1) The tunnel portal landscape blends with highway landscape. As a partial landscape, the tunnel portals divide the highway into

several sections but should be a part of the whole highway landscape. In spite of local variations, all tunnels in one highway should be considered altogether in portal landscape designing.

- (2) The tunnel portal landscape blends with the existing natural landscape. The portal must fit with the existing environment such as nearby villages, buildings, beauty spots, farmland, mountains, rivers, gorges, lakes, forest, grass land or desert along the way.
- (3) The tunnel portal landscape provides a connection to the local population. The connection between landscape and people is the most important relation because the landscape is for man though it is man-made. The tunnel portal landscape design should be guided by popular esthetics, so as to better satisfy popular demand.

First consideration should always be given to the needs of the people and provide favorable natural and cultural environments to drivers and passengers in tunnel portal landscape designing.

5.6. Economic principle

The economic principle does not mean just saving money but means the tunnel landscape designers should try their best to obtain a better visual look at a small cost. Compared with a flashy design, a scheme with simple structure and less material but with abundant cultural connotation should be the first choice in portal landscape design.

6. Criteria for highway tunnel portal landscape design

6.1. Landscape elements of highway tunnel portals

The landscape elements of highway tunnel portals principally comprise the direct, indirect and related elements (Zhang, 2008):

- (1) The direct element is the portal structure, which consists of the engineering component and decoration structure. Thus, the engineering component mainly means the supporting structure of the side and front slope, and the decoration structure often means the pure ornament, such as the framework, pillars and decoration gate.
- (2) The indirect elements include the slope surface, median strip, tunnel name, directional system, etc.
- (3) The related elements mean the correlative background near the tunnel location, which mainly include the natural environment and human environment. Specifically, the related elements can be divided into road alignment, affiliated facilities, lighting installation, and the nearby villages, buildings, beauty spots, farmland, mountains, rivers, gorges, lakes, forest, grassland or desert.

6.2. Landscape design flow of highway tunnel portals

Obviously, tunnel portal landscape design is not just a portal building and structure design, but is the landscape design of the tunnel entrance section. The contents include the portal buildings and structures, the side and front slopes, vegetation methods, directional system, the name plate, and lighting design. The design flow is generalized as a flow chart shown in Fig. 7 in this paper.

6.3. Landscape expression forms of highway tunnel portals

Highway tunnel portals can be expressed through many forms, which are summarized as a table shown in Table 1.

7. The typical practices of highway tunnel portal landscapes in China

7.1. Variety of geometric types of tunnel portals

Geometric types of tunnel portals, such as linear and curvilinear geometries, are frequently used in China, as shown in Figs. 8 and 9. In general, a linear geometry of a tunnel portal appears grand,

powerful, steady and guileless while a curvilinear one is more gentle, elegant, affecting and pleasing.

7.2. Integration with local cultures

Nowadays, environment and landscape awareness leads to a great improvement in tunnel portal design in China, by which the local culture factors are often taken into account.

7.2.1. Anthropological aspects

The Baihuashan tunnel located at Xishuangbanna, in the Dai nationality autonomous district of Yunnan Province exhibits a representative architectural style of the Dainationality and substantially displays the Dainationality culture. For instance, the top of

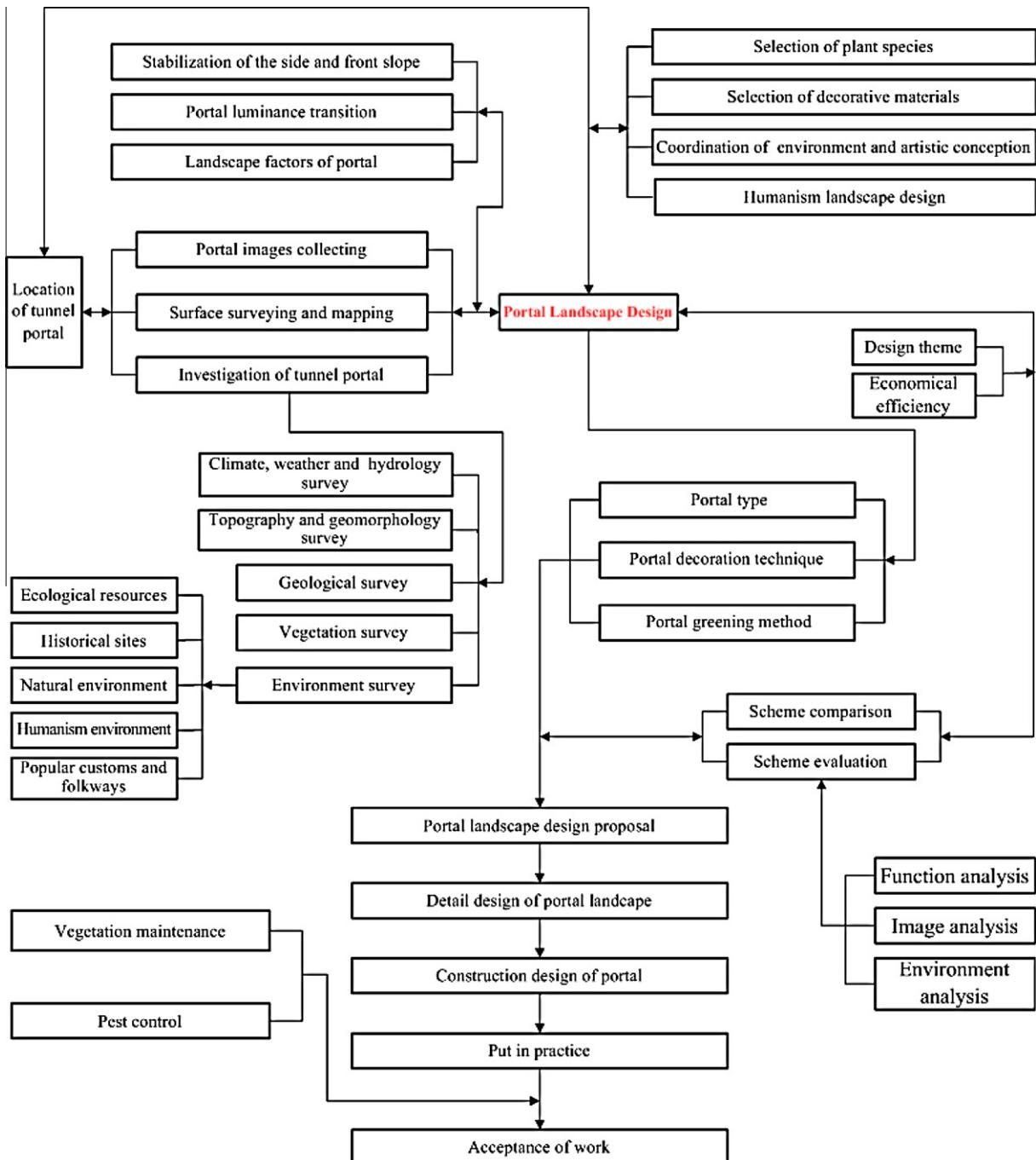


Fig. 7. The flowchart of tunnel portal landscape design.

Table 1

Landscape expression forms of highway tunnel portals.

Design variants	Characteristics and realization	Figure references
<i>Portal shape</i>		
Geometric types		
Linear figure	Grand, powerful, steady and guileless	Fig. 8
Curvilinear figure	Gentle, elegant, affecting and pleasing	Fig. 9
<i>Structure</i>		
The end wall tunnel portals	Normally, the end wall tunnel portal is used frequently because of the simple structure and small project quantity, and it is simple and easy to construct. However, it is often embellished and decorated, and then forming all sorts of complicated and graceful landscapes. Sometimes, to the end wall will be added two wing walls	Figs. 8, 10, 18, 23, 28, 40a–c
Protruding portals		
Vertical cutting	The protruding portal is often realized by an open cut tunnel with certain length, which decreases the deep and wide excavation to the original mountain and seems simple and clear, natural and smooth. The protruding portal's slope is often vegetated by planting trees	Figs. 34a and b, and 38d
Direct cutting		Fig. 38a and b
Inverse cutting		Fig. 38e
Bell mouting		Figs. 9b and 34c
Abnormal portals	Abnormal portal is a portal with a particular special decoration or that has been beautified for some special function	Figs. 21 and 30
No portals	The portal hides in the surrounding environment and cannot be differentiated from the environment easily. This kind of portal has been used in good geological conditions	Figs. 37 and 38c
<i>Colors and pattern</i>		
Colors	To embellish the tunnel portals through different colors	Figs. 13 and 18, 23, 24–29, 30, 40
Pattern	Tunnel portals often use the muted colors in decoration, such as the steel gray of concrete, the natural color of freestone, so as to avoid visual contrast. But sometimes there are some vivid color portals Such as the art forms of sculpture, painting and calligraphy	Figs. 28 and 29
<i>Decoration skills</i>		
Architectural	Using a simplified architecture structure to decorate the portals	Figs. 10, 13, 15–17, 21 and 24
Sculptural	Bringing a sculpture or embossment to the tunnel portals' decoration, especially the end wall tunnel portals	Figs. 28, 29, 40b
Facing	Special facings are often used in traditional tunnel portal decoration, which adopts cement, ceramic tile, decorative plate, or some other facing material to cover the end or wing walls, and forms a diverse ornamental design with different textures and colors	Figs. 8, 13, 15–17, 25 and 26
Shaping	While ensuring structural safety, the shape of the end wall or some other partial structure may be changed by varying the geometric type, putting up imitation stones so as to beautify the portal or express some cultural connotation	Figs. 10, 12, 18, 21, 23, 25, 27 and 30
<i>Construction material</i>		
landscaping	To create some portal landscape through construction materials, such as the ceramic tile, granite, concrete, freestone and colorized natural stone coating	Figs. 13, 15–17, 24–30, 36, 37 and 40
Areal landscaping	To beautify the tunnel portals through greening the side and front slope, the front of the tunnel entrance, the space between the two holes, the end or wing wall, etc.	Figs. 12, 25, 26, 34a and b, 38
<i>Generalization and abstraction</i>		
Ethnological aspects	To display some distinguishing culture and landscape through generalizing it into actual lines, structures, patterns and shapes with imagination and abstraction	Figs. 12, 13 and 15–17
Regional culture		Figs. 18, 21 and 23–27
Historical culture		Figs. 28 and 29
Typical landscape		Figs. 30 and 39
<i>Tunnel shed</i>		
Ordinary tunnel portals	To mitigate the difference in lightness between the inside and the outside of the tunnel at the portals	Fig. 34
Shed structure adjacent to mountain	Shed-tunnel structure leans against the hill without cutting into the mountain, which joins the surrounding landscape to form a harmonious entity	Figs. 32 and 33
Tunnel shed for portals of tunnel group	The tunnels with very small distance in tunnel group are often connected by a shading shed, so as to reduce the lighting variation and improve driving safety	Fig. 35

the portal (shown in Fig. 10) exactly resembles the roof of bamboo houses of the Dai nationality (shown in Fig. 11), reflecting the approach to this distinctive town.

Xexianggu tunnel is another tunnel located in the same city with portals mimicking a crown of a Dai nationality princess (shown in Fig. 12). The radius of the portal arc is perfectly matched with the shape of a crown of a Dai nationality princess. Further examples are bamboo houses and arbors with Dai nationality characters distributed near the tunnel portals. All these designs result in the incorporation of tunnel portals into local culture as well as the surrounding tropical rainforest scenery (Dai, 2008).

Rierlang Mountain Tunnel (shown in Fig. 13), located on No. 213 national trunk way in the Tibetan people cluster area of

northwest Ruoergai County, Sichuan province, uses portals with typical Tibetan features:

- (1) There are Tibetan carved patterns at the bottom of the portal gate post, and the rest areas are painted with a red natural stone coating.
- (2) The end wall of the bench tunnel portal is covered with a white and red natural stone coating, and decorated with cultured stone. The topping of the portal was designed as two-storey Tibetan structure (shown in Fig. 14) with Tibetan ornamental decorations on it.



Fig. 8. Linear geometry of tunnel portal (the image was provided by Zhang, T. Z.).

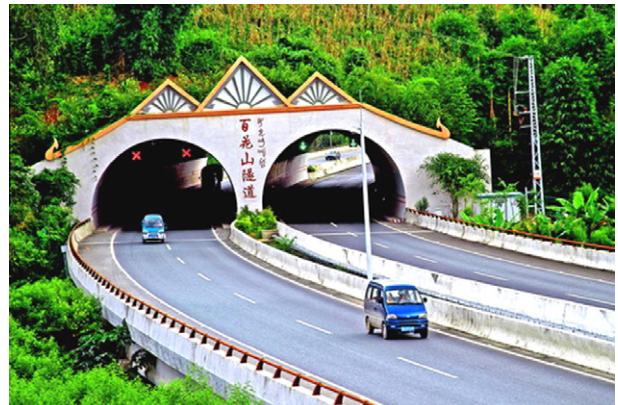


Fig. 10. Portal of Baihuashan tunnel with Dai nationality architectural factors (<http://lvyou.wanjingchina.com/bencandy.php?fid=40&aid=136530&page=3>).



(a)



(b)

Fig. 9. Curvilinear figure of tunnel portals (the image was provided by Li, J. F.).

(3) The tunnel name was written both in Mandarin and Tibetan characters.

There are several other portals of highway tunnels demonstrating typical Tibetan characteristics, such as the Erlangshan Mountain Tunnel located on the No. 318 national trunk way (shown in Fig. 15), the Galashan Mountain Tunnel on the airport express way from Lhasa to Gongga airport (shown in Fig. 16), and the



Fig. 11. Bamboo houses of Dai nationality (the image was provided by Zhang, T. Z.).



Fig. 12. Portal of Yexianggu tunnel with crown of Dai nationality princess (the image was provided by Zhang, T. Z.).

Zhegushan Mountain Tunnel on the No. 317 national trunk way (shown in Fig. 17).

7.2.2. Regional culture

China is a multinational country with diverse regional cultures, such as the Wuyue culture, Qilu culture, Yanzhao culture, Huxiang



Fig. 13. Portal of Rierlang Mountain Tunnel with typical Tibetan feature (<http://attachments.motorfans.com.cn/2010/10/26/MFMDOV8zt5549.jpg>).



Fig. 14. Tibetan structure (<http://www.51yougo.com/photos/photo.aspx?id=10860>).



Fig. 15. Portal of Erlangshan Mountain Tunnel (<http://fengyunbike.com/thread-11982-5-1.html>).

culture, Bashu culture, San-qin culture, San-jinculture, Central Plain culture, Guandong culture, Huizhou culture, Kechiah culture, Prairie culture, and Taiwan culture, etc.

At present, regional cultures are often taken into account during the design of tunnel portals. Several representative tunnel portals, which effectively recognize regional cultures, will be introduced below.



Fig. 16. Portal of Galashan Mountain Tunnel (http://59766.com/myphoto/pic_remark_1782.htm).



Fig. 17. Portal of Zhegushan Mountain Tunnel (the image was provided by Qiu, Y. L.).

7.2.2.1. Huizhou culture. The Huizhou culture involves all the materials and spiritual fortune created by the Huizhou people. One of the most distinctive characteristics of the Huizhou culture is reflected in its architecture, such as residential houses, carving art, ancestral halls, and commemorative paifangs.

The expressway from the Yellow Mountain to Taling and Taolin passes through Huizhou. In this project, the designers fully integrated Huizhou cultural elements into the landscape design of the tunnel portals.

The portal landscape design of No. 1 Guanpujie tunnel (Fig. 18) applies an arch-bridge, a basic structural element in a Huizhou garden (Fig. 19). It emanates elegance and grace with the grayer bridge body matching the white hollow-carved banister. Moreover, the arch-bridge-shaped portal fits with the surrounding landform perfectly, conferring a considerable level of poetic romance upon the green mountains around it.

The commemorative paifang (shown in Fig. 20) is a significant cultural symbol of Huizhou culture, which reveals the ethics and patriarchal ideology of the ancient Huizhou people and represents merit, loyalty, and filial piety.

A commemorative paifang was introduced into the portal design of the Majinlin tunnel. The end wall was tailored to simulate a commemorative paifang structure (shown in Fig. 21), which expresses local culture elements and great vigor.

Notably, the specific characteristic of the Huizhou architecture is a careful way of the buildings being laid out (close attention to local geography). The so-called “horse’s head” wall (shown in Fig. 22) is classically and extensively used within Huizhou



Fig. 18. Portal of No. 1 Guanpujie tunnel (Liu et al., 2010).



Fig. 19. Arch-bridge of Huizhou garden (<http://www.nipic.com/show/1/75/078cf5cb1522ff62.html>).



Fig. 20. Commemorative paifang in Huizhou (<http://www.zhuchiren.org/jjzg/bwzg/201005/t624472.htm>).

architecture. It is generally tall and fire-proof with auspicious implications since the horse is regarded as a good luck animal by the locals.

The design spirit for the portal of the Zhongcunnan tunnel (shown in Fig. 23) originated from the "Horse's head" wall. The

top of the portal appears to be a ladder shape and Huizhou windows are well inlaid in the gray end wall. This design concept modifies typical Huizhou architecture to display the grandness of the portal.

7.2.2.2. Hakka culture. During a long period of social practice and work, the Hakka people have integrated historical and new cultures and created their own distinctive culture, the Hakka culture.

The expressway from Meizhou city to Heyuan city is approximately 120 km long and connects developed areas and the east mountain regions of Guangdong province. It crosses right through the central region where the Hakka culture lives. The construction materials of the tunnel portals in that route originated from the folk houses and customs of the Hakka people, embodied in the Hakka cultural characteristics, such as the distinctive architecture, folk-custom, daily life and colors. The portals give passengers a taste of the Hakka's culture. The portal of Dongshangang tunnel on that route is a good example (shown in Fig. 24).

7.2.2.3. Xiangxi culture. Western Hunan, or Xiangxi, is a fascinating region and has been the area inhabited by the Miao, Tujia, Hui, Yao, Dong and Chuang peoples since ancient times. These diligent and wise western Hunan people have created resplendent regional cultures and charming folk customs.

The expressway from Changde city to Jishou city within western Hunan province was completed in 2008. The tunnel portals especially emphasized Xiangxi cultures by applying the local landscape elements, including the South Great-wall, Miao Stockaded village, the Hanging house of the Tu-ethn, the Miao drum, dragon boat and Tujia totem, etc. Plant decoration, imitation of ancient timber and plastic stone were used to dress the tunnel portal landscape, as shown in Figs. 25–27. For making the tunnel portal landscape closer to the nearby natural environment, muted colors were used to decorate the end wall surface and an ecological retaining wall was used as the wing wall.

7.2.3. Historical culture

China, one of the world's most ancient civilizations, has splendid historical cultures. Designers have attempted to blend the Chinese historical culture into the creation of tunnel portal landscapes as shown in the following examples.

7.2.3.1. Tea culture. Chinese tea enjoys a history of over 5000 years, during which time a series of unique tea cultures have come into being. Tea culture is one of the common traits shared by all the 56 ethnic groups in China. Many Chinese people believe that a day is imperfect without having a cup of tea. The Jixiongshan tunnel (shown in Fig. 28) on the expressway from Meizhou city to Heyuan city in Guangdong province is a good tribute to the distinctive tea culture. The portals were decorated with tea-related



Fig. 21. Portal of Majinling tunnel (Liu et al., 2010).



Fig. 22. "Horse's head" walls in Huizhou (<http://www.nipic.com/show/1/75/6f44013c02acf47c.html>).

objects, demonstrating the full-bodied tea culture in that area to passers-by.

7.2.3.2. Porcelain culture. Second only to tea, perhaps the most important contribution China has made to people's life was "china" itself. When Marco Polo returned to Venice in 1295, he brought with him countless rare treasures from China, among which the Longquan celadon was one of the most valuable treasures and more precious than gold. Longquan, a famous celadon city, located between Southwest Zhejiang and Fujian province, earns its name as one of the earliest porcelain types in Chinese history.

The Mifengling tunnel, situated on the No. 54 provincial highway within Longquan city, shows its celadon culture to travelers with particular portal landscape: china. Bowl models were used as the end wall, both sides of which were inlaid with a celadon Ge-kiln artistic bottle, Di-kiln celadon appreciation kettle and celadon carp fish hanging plate comprised of special triangle porcelain shreds (shown in Fig. 29).

7.2.4. Local unique scenic spots

For some highway tunnels located in particular scenic spots or on the way to such a spot, the special decoration on the portals having the characteristic of that spot will enhance the expectation of the visit. This not only expands the scope of the scenic spot, but also is good advertising for the spot.

The portal decoration (shown in Fig. 30) of the first Qingshuigou tunnel on the expressway from Kunming to the stone forest in Yunnan province is just like the shape of the stone forest, which is a group of great sculptures of different shapes produced by con-

stant seeping of rain through the cracks in the limestone over a very long geological time (shown in Fig. 31).

The portal of the first Qingshuigou tunnel is a good landmark and lets visitors see the stone forest before arrival in the stone forest spot.

7.3. Environmental conservation

For a long time, deep excavation and filling was a common practice in highway construction, and highway tunnels were rarely applied to traverse mountains for economic reasons and the absence of environmental consciousness. This old-fashioned concept has been radically changed in recent years. Environmental awareness is clearly reflected in the recent highways, as tunnels are often used to protect the environment.

Fig. 32 shows the Laoshan No. 2 tunnel on the Ning-Huai (Nanjing city to Huai'an city in Jiangsu province) expressway. It is known as the "shed-hole adjacent to the mountain" because one side is adjacent to the mountain while the other side is supported by 33 posts, each having a length of 12 m. The top of the shed was overlaid with original soils following the closure of the upper-side lining structure. The shed-tunnel structure leans against the hill without cutting into the mountain, which joins the surrounding landscape to form a harmonious entity. The "snow shed adjacent to mountain" solution of Laoshan No. 2 tunnel is not only an attractive sightseeing spot, but a pattern that combines safety and environment protection.

Fig. 33 shows a picture of Longpu tunnel on the expressway from Yellow Mountain to Taling and Taolin within Anhui province. Even if the arc rib lining differs from previous styles, it has the same level of satisfaction as compared with the Laoshan No. 2 tunnel (shown in Fig. 32).

7.4. Giving prominence to light transition at tunnel portal

7.4.1. Light transition for an ordinary tunnel portal

It was mentioned before that the required brightness inside the tunnel can be adjusted by mitigating the rapid transition between light levels inside and outside. The lighting adjustment is also accounted for in the landscape design of tunnel portals. In other words, lighting adjustment and landscape functions can be combined. Fig. 34 shows a series of pictures of highway tunnel portals, which give prominence to the adjustment of lighting through hollow-carving in open cut tunnel lining or through using a light reduction canopy.

7.4.2. Light reduction for portals of a tunnel group

The tunnel group frequently appears with the fast development of mountain expressways in recent years. And the distance



Fig. 23. Portal of Zhongcunnan tunnel (Liu et al., 2010).



Fig. 24. Portal of Dongshangang tunnel (the image was provided by Zhang, L. C.).



Fig. 26. Portal of Tongmuwan tunnel (<http://tcliuke.blog.163.com/blog/static/677638672010101483328691/>).



Fig. 25. Portal of Queixi tunnel (<http://tcliuke.blog.163.com/blog/static/677638672010101483328691/>).

between tunnels varies from tens of meters to hundreds of meters. Sometimes several tunnels almost are linked together. The typical characteristic of a tunnel group is the narrow portal space and the limited field of view between tunnels. So, drivers have to experience the visual environment changing from dark to light to dark frequently in a tunnel group, and that will bring negative effects on driving safety. Therefore, tunnels with short distance intervals have often been connected by a shading shed, which forms a special form of tunnel portal landscape (shown in Fig. 35).



Fig. 27. Portal of Liangshuijing tunnel (<http://tcliuke.blog.163.com/blog/static/677638672010101483328691/>).

7.5. Blending into the surrounding environment

The previous sections have asserted that the portal landscape should correspond to the classical concept of Chinese garden—"though it is man-made, it seems to be natural". Some practical examples of this are shown in Figs. 36–38.

The Wulaofeng tunnel (shown in Fig. 36) is located near West Lake in Hangzhou city, Zhejiang province. The portal makes use of



Fig. 28. Portal of Jixiongshan tunnel (the image was provided by Zhang, L. C.).



Fig. 31. The stone forest (<http://www.tcalliance.org.cn/home/?action=viewthread-tid-4577>).



Fig. 29. Portal of Mifengling tunnel.



Fig. 32. Photo of Laoshan No. 2 tunnel.



Fig. 30. Portal landscape of the first Qingshugou tunnel.



Fig. 33. Photo of Longpu tunnel.

planting and artificial stones of different texture. The tree planting and the stacked artificial stones are well blended into the surrounding environment, and show a harmonious and natural landscape.

Fig. 37 shows a picture of Qiepengxi tunnel on the expressway from Changde city to Jishou city within western Hunan province, and provides a similar natural-looking environment as compared with the Wulaofeng tunnel (shown in Fig. 36). Especially the color and texture of the artificial stones, along with the plantings blend the structure well with its environment.

Fig. 38a shows a picture of a tunnel portal in Nanjing city, the successful greening of which makes it form a harmonious whole with the surrounding environment.



(a)



(b)



(c)

Fig. 34. Some tunnel portals for light transitioning in China.

The pictures (b–e) of Fig. 38 are tunnel portal landscapes on the expressway from Xi'an city to Hanzhong city in Shaanxi province. They all are well blended into the surrounding environment with protruding portals and greening approach.

7.6. Nonrepresentational tunnel portal landscape

Symbol and metaphor are often used in Chinese culture. Symbolism means expressing some nonobjective concepts, ideas or feelings. For instance, the four directions were symbolized by four beasts, and the universe by the round sky and square earth. Meta-

**Fig. 35.** A shading structure between tunnel portals in a tunnel group.**Fig. 36.** Portal of Wulaofeng tunnel (the image was provided by Du, H. D.).**Fig. 37.** Portal of Qiepengxi tunnel.

phor means revealing some invisible things with hint, association or recollection.

Niujiashan tunnel, situated on the No. 1828 provincial highway in Hunan province, is a typical example using symbols and metaphors in its portal landscape design. A pair of curve wings

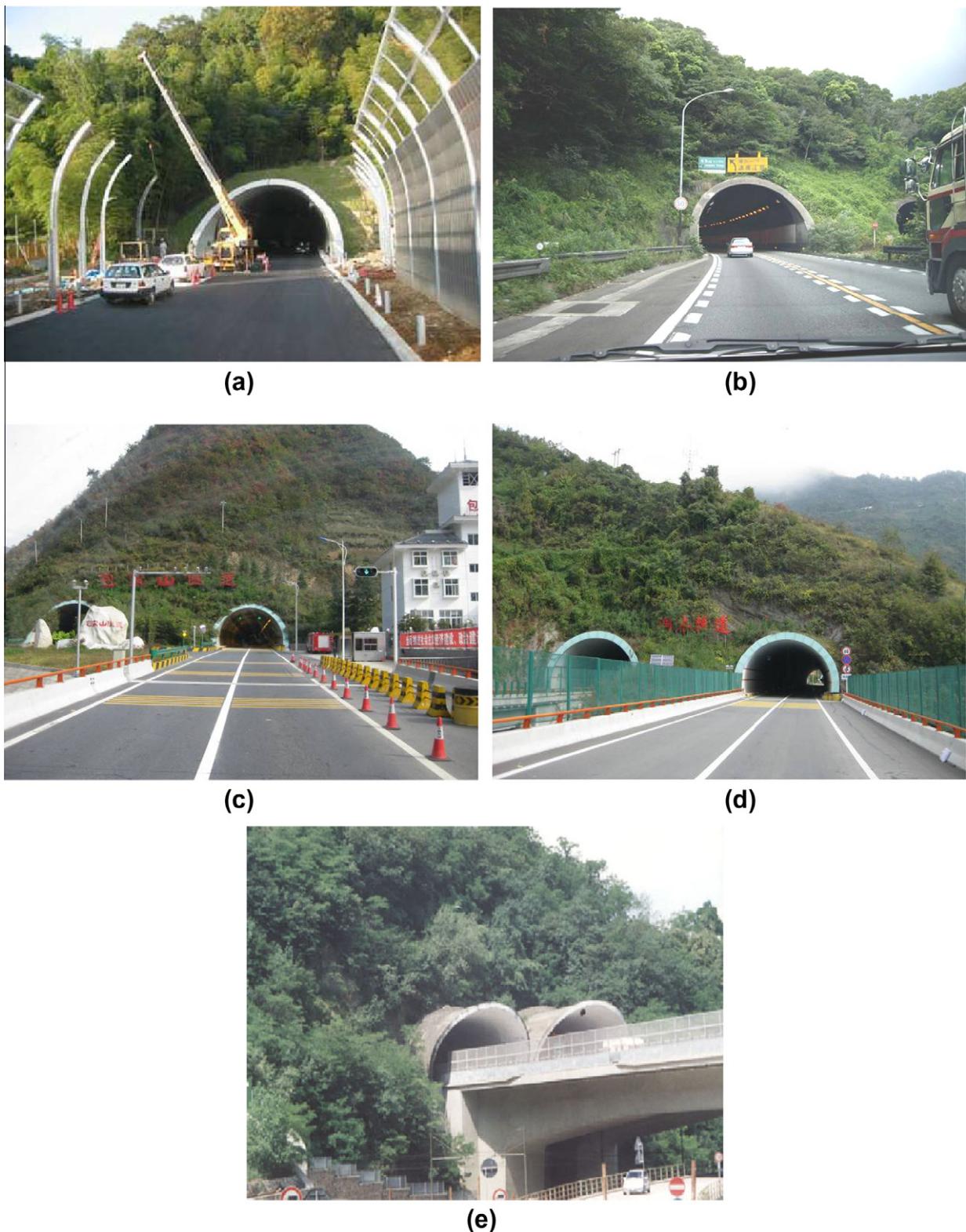


Fig. 38. Some tunnel portals well blending into the surrounding environment in China.

protrudes from the portal's end wall (shown in Fig. 39), which not only is used to maintain stability of the two side slopes, but also is representing the Niujiaoshan Mountain since, in Chinese, the Niujiao means ox horns, and which are just like the curved wings.

7.7. Special decoration

To some extent, tunnel portals offer a stage where designers can manifest their own esthetic ideas. In China, there is an increasing



Fig. 39. Portal landscape of the Niujiaoshan tunnel (http://www.hczjgs.cn/hczj/T_ProductShow.asp?ProductID=22&SmallClassID=11&BigClassID=44).

number of highway tunnels with diverse portal designs in recent years, which have greatly enriched the tunnel portal landscape and formed a new idea of portal landscape design (shown in Fig. 40).

8. Discussion

We can see from the above mentioned analysis that much attention has been paid to tunnel portal landscape design in China

in the last decade. But, there are still some problems worth considering and discussing:

- (1) Is the highway tunnel portal landscape good for driving safety or not?

The inherent conflict was raised earlier between making a tunnel portal attractive and interesting and creating a distraction for drivers that will affect driving safety. Therefore, how to make an appropriate choice between attracting and excluding drivers' attention, so that the tunnel entrance driving is safer is a continuing issue that needs further study.

- (2) Eye-catching or simple?

It has been shown that both eye-catching and simple types of portal landscape exist simultaneously in today's China. Some experts (Hong and Wang, 2010) consider the tunnel portal landscape different from architectural decoration and that it should not seek grandeur and an artificial style. They argue that the simple and unadorned portal should be the first choice in tunnel portal landscape design. In the author's opinion, we should not take a sweeping approach on this point, as some eye-catching portal landscapes are still well blended into the surrounding environment and create an enjoyable experience, such as the portal landscapes shown in Figs. 10, 13, 15–17, 24, 25, 28 and 29, etc.

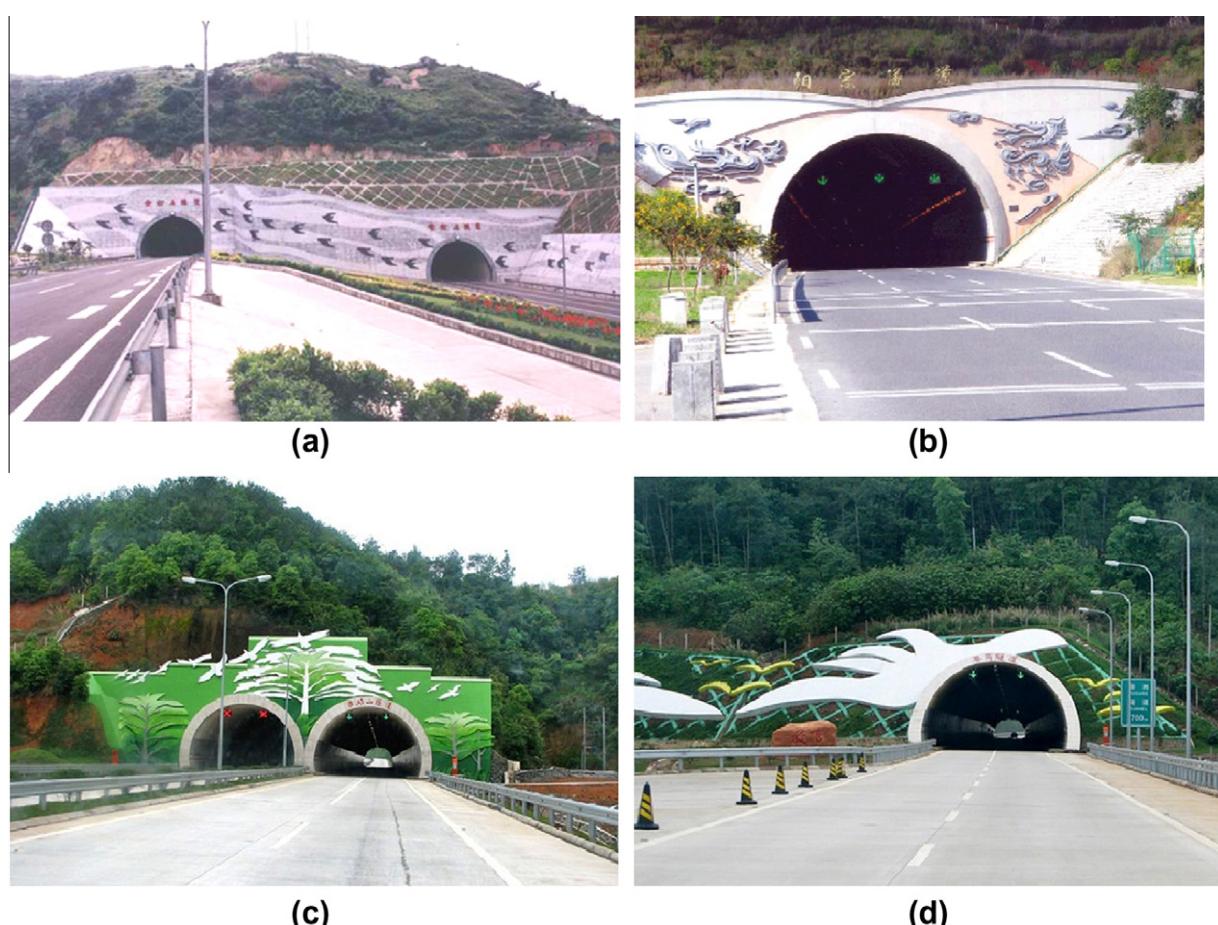


Fig. 40. Some tunnel portals with specially decoration in China.

(3) Static or dynamic landscape?

The surrounding landscape is obviously a dynamic landscape for vehicles when passing through the tunnel entrance, and the field of view and definition is continuously changing. But today, most highway tunnel landscape design is merely a static design. So, how to consider and estimate the dynamic characteristic of the tunnel portal landscape is another problem in front of us.

(4) Beautiful or economic?

Beauty of the tunnel portal landscape is a worthwhile expense but there is no doubt also that economic efficiency cannot be neglected in tunnel portal landscape design and construction. Thus, we need beautiful highway tunnel portals on the one hand and to reject extravagant portals on the other hand. So, the economic efficiency analysis and comparison are necessary in tunnel portal landscape design, which unfortunately have not been put on the agenda in China at present.

Generally speaking, the present situation of highway tunnel portal landscape design can be summarized as: beginning to be practiced, having no systematic theoretical guidance, and not yet fully integrated into overall highway and tunnel design.

9. Conclusions

The main results obtained from the study described in this paper are as follows:

- (1) The significance of landscape design for mountain highway tunnels can be summarized as: preventing travel fatigue, visual adaptation, communicating and displaying culture, land marking, and environmental protection.
- (2) The principles of landscape design of mountain highway tunnel portals can be summarized as: safety, minimal impact, physiological, regionalism, blending and economic principles.
- (3) Landscaping tunnel portals is a comprehensive art, involving creativity, landscape architecture, architecture, local culture, bionomics, psychology, environment protection, optical techniques, safety techniques, and the application of new materials and new technical arts.

(4) Tunnel portal landscape design requires further collaborative and intensive interdisciplinary studies.

(5) The design methods for tunnel portal landscape are diverse. Many aspects such as the local traits, folk culture, surrounding environment, stabilization factors, and the designer's understanding of beauty, contribute to elements in the design.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:[10.1016/j.tust.2012.01.001](https://doi.org/10.1016/j.tust.2012.01.001).

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