Computer Aided Landscape Design for Freeway "Points", "Lines" and "Planes"

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***Abstract* - 3D and planar design software, as an indispensable aiding tool for the design industry, is widely used in architectural and landscape designs. This paper centered on the CAD-based study of comparatively important issues existing in freeway landscape designs - landscape "points" (entrances, exits and architectural elements), "lines" (roadside green belts) and "planes" (protecting slopes and rock walls) - in association with actual cases, and bright forward some exercisable design methods and philosophies. This study explained how to solve the series problems of freeway's landscape designing by computer.**

Keywords- Computer aided design; Freeway landscape; Designing method

I. STATUS QUO OF FREEWAY LANDSCAPE

Freeway is playing an increasingly important role in our daily life. Same increasing is people's expectation of roadside landscape and functions. As a result, study of freeway landscape has become an important program related to multiple subjects. [1] With the furthering of freeway construction in China, roadside landscape problems are gradually exposed: on the "point" level (including entrances & exits, architectural sculptures), the landscape entities are devoid of aesthetic feelings; the cultural nature, spatial scale and building materials are disorderly and unsystematic; and the architectural elements in series are unreasonably spaced; on the "line" level (the linear landscape formed by roadside vegetation), improper vegetation seed brings in survival difficulties of trees or even invasion by foreign species, and spacing between and size of the vegetation are inappropriately schemed; on the "plane" level (the continuous plane landscape formed by protecting slopes and rock walls), both the above-mentioned problems and deformation of the plane image under high driving speed exist.

To solve these problems, investigation and analysis of current freeway landscape are necessary. Besides, it is advisable to experiment on the landscape design projects of freeway sections, and use the experimental results to guide the rational landscape planning of other areas. [2] However, due to the giant workload of freeway construction, function and safety are the first priorities to be considered, and it is unrealistic to take one road section as the experimental materials for landscape design. Therefore, we apply to computer modeling to simulate the actual freeway landscape, and make analysis and evaluations based on it to work out the best landscape design methodology and philosophy.

II. COMPUTER AIDED PROBLEM ANALYSIS

A. CAD software concerned in this study

Instead of the flowery expression of landscape, this study focuses on people's dynamic perception of roadside landscape when they travel at a high speed on freeways. Therefore, we choose the popular Sketch Up software (7.0 professional, hereinafter shortened as SU, launched by Google Inc.) as our designing tool, which is advantaged by its detailed design process, the fast and accurate modeling, and the function of exporting dynamic range rendering animations.

To create the effect drawing, we come to the help of Photoshop software (hereinafter shortened as PS) released by Adobe Systems Inc., which is also popular among landscape designers.

B. Experimental subject

In this study, the author takes two ongoing freeway landscape design cases as the experimental subjects, which are (1) The Cultural Construction for Chifeng Freeway in Inner Mongolia Autonomous Region (Project source: Communication Culture Research Institute of Transport Management Institute, Ministry of Transport of PRC); (2) Traffic Safety-based Study of Key Technologies in Freeway Landscape Designs (Project source: China Academy of Transportation Sciences, MOC).

C. Research methodology

(1) Preparation of experimental materials (landscape entities): Use SU to build the model for the roadside landscape design schemes, and create 3D animation based on the model to simulate the dynamic effect observed by people in running vehicles on the freeway. For the detailed parts of landscape entities, use PS to visualize the effect drawing of the landscape model exported by SU; then carry out all-practical imitation experiments.

In the process of animation and picture creation, several experimental groups are established as per the variables of running speed, size, spacing and appearance of landscape entities. Each group has one variable (for example, different

running speed for the same landscape section, or different spacing between landscape points under the same running speed). In the same experimental group, subgroup and number by gradient the experimental results under the same variable, then make an overall appraisal of the landscape design methods based on the different scenarios, and finally work out a function-like method.

(2) SD method: "Semantic differential" (SD) method is an investigation and analytical method widely used in psychology, market survey and cultural study. This study applies the SD method to qualitatively analyze the experimental materials, and determines the quantification rules of every design segment in association with the SD analytical result under every single variable. In the SD method, questions and scales are two essentials. One scale is divided into seven grades, with two adjectives completely contrary to each other as the two ends. For example, the seven grades may be: (i) "excellent", (ii) "very good", (iii) "good", (iv) "normal", (v) "bad", (vi) "very bad", (vii) "extremely bad". Participants of the experiment shall select one of the seven options based on their emotional evaluation upon the raised issues (here refers to the animations and pictures). Their evaluations will be used for factor analysis. SD method is advantaged by straightforward results, flexible application, and convenience for conceiving and scoring. [3] To get the accurate and authentic feeling of the simulation scene, several regular drivers and passengers of the exact freeways were invited in the research experiment.

(3) Conclusion: With the experimenters' feelings and evaluations of the SD method-based experiment, we can decide the favorite scenario and favorite landscape design for freeway users, and put forward certain design guidelines on this basis.

III. Problem solving

A. Designs of landscape "point"

1). Entrances and exits

Entrances of many freeways are designed as the "name card" of the road section by erecting landmark points fitted in the surrounding greenbelts. As the first highlight for the roadside landscape of the section, the design of this "point" deserves special attention.

Fig. 1

One subject of this experiment is an entrance to the Hegang-Dalian Freeway of project (2), where there is a triangle greenbelt to be placed with a landmark landscape. In the designing period, several elements with the connotation of Jilin City's history and culture came into the picture, including North-east tiger, deer, ginseng, ship… The former three are Jilin City's specialties. The "ship" idea originates from the old name of Jilin – "Jilin Wula", which in the Manchu language means cities along rivers. Based on the different design ideas, different landscape entities were designed and effect drawings were created. Then all the design alternatives were analyzed based on the SD method, and finally the "ship" plan was selected. After the outline was fixed, shape and material of the ship were put on the agenda, followed by the illustrations of the features of different materials: metal sculpture is florid but too expensive and corrosion-prone; and stone sculpture is on the contrary. [4] Through SD analysis, the plan as shown in "Figure – 1" was confirmed: plums were dry laid to the ship-shape, with metal mast hung by eye-catching slogans.

Therefore, we can sum up the requisite features for such entrance landscape types: (i) eye-catching; (ii) representing local culture; (iii) graceful and durable.

2) Architectural elements and sculptures

With the moving of the vehicle, all the landscape points of the freeway show up one by one. The optimum spacing between the points and the size of single points are evaluated as following: by SU modeling, a one-kilometer road section is created, with landscape elements decorating roadside greenbelts. To achieve the intelligible and intuitionistic effect, a simplified global sculpture is placed on the central greenbelt, and a cultural totem pole is placed on the outer side. Adjust the observation angle of the model according to driver's visual angle (see Figure -2), then export several animations under different running speed as the dynamic scenes observed by drivers and passengers.

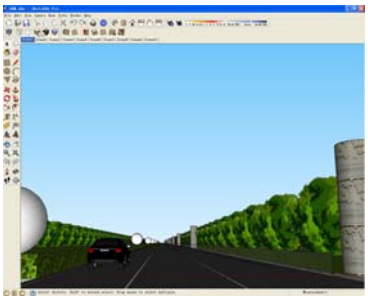

Fig. 2

In the first experimental group, set the average running speed at 90km/h (25m/s), then select the best landscape scene based on the comfort level sensed by people under different spacing and sizes of points. The concrete steps are: in the SU model, set one scene every 100 meters along the travel direction of the one-kilometer section (SU can export animation through scene switches), and set the switching time of every two scenes at four seconds (i.e. to control the

advance speed of sight at 25m/s); zero the dead time of every scene (see Figure-3). In this way, the animation effect seen by experimenters is equivalent to running smoothly at 90km/h on the road section. In this group, make constant the speed and landscape size, and choose the spacing between totem poles and global sculpture as the variable (In Figure-2, the spacing is 100m). Then separately adjust the spacing to 50m, 150m and 200m, and create the corresponding animations. Play the animations simultaneously and analyze by the SD method the comfort level of each spacing sensed by experimenters. In this way, the optimum spacing is achieved.

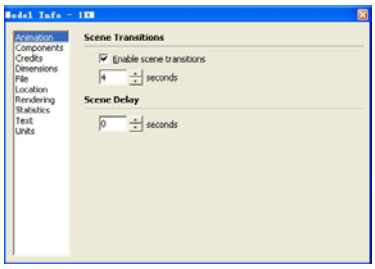

Fig. 3

After the above experiment, let's assume the optimum spacing is 100m, and evaluate the comfort level under different running speed (set the speed at 80km/h, 90 km/h, 100 km/h, 110km/h and 120km/h respectively, and select the speed that provides the highest comfort level). Put these two experimental groups into overall consideration, we can get the different optimum spacing of landscape points of road sections with different speed limits. Same, we can get the optimum size, material and appearance of single landscape points. With these two experiments, we can educe the landscape design principle closely related to landscape observers.

Research says that to clearly see the landscape on freeway, the minimum fixation time is five seconds. [5] Therefore, during this period of time, the travel distance of vehicle is the length of landscape, i.e. the spacing of landscape points or the width of landscape planes (see below). Then we get the functional relation as shown in Figure-4.

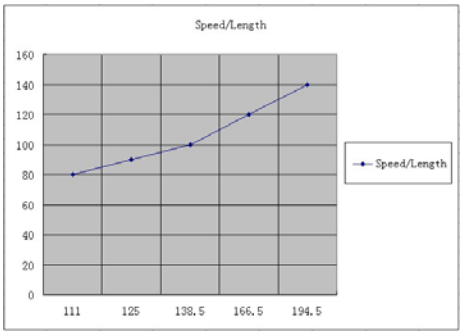

Fig. 4

B. Designs of landscape "lines"

Generally speaking, there are three considerable factors for the selection of freeway roadside vegetation: firstly, to match tree species with site and focus on indigenous tree species; secondly, to allocate the suitable proportion of fast-growing species and slow-growing species, and of deciduous species and evergreen species; thirdly, to make an overall planning of vegetation colors and the space configuration of trees, shrubs, vines, grass and flowers to enhance the layer sense of the landscape. [6]

The experiment chose a road section of Project (1), where the weather is dry and cold. Suitable roadside trees are poplar, ceiba and dryland willow. Site pictures were PS processed to the effect with different roadside tree species, and then the best scene was chosen. It shall be noted that some road sections used sea-buckthorn as the roadside vegetation, which is characterized by fast growth and no natural enemies. Consequently, it grew out of control and caused influences to traffic safety. Therefore, we must put the ecological principle into consideration when we choose tree species，and use those whose growth can be artificially controlled.

Tree size and planting density shall also be considered to provide the antidinic function. With reference to the above-stated methodology and functional relation, we designed different sizes of trees in the SU model, then exported the animation and pictures, and chose the best tree size based on the SD method. With this best size, we got the best planting density by the same procedure. Different road sections and areas lead to different conclusions. Before conducting detailed designs, we shall make a brief investigation into local features and tailor the most appropriate design scheme.

One important issue is that in creating pictures and animation, we shall attach same importance to both the appearance and the authenticity; otherwise the designs will be "empty talks". See Figure-5, the first picture is the actual scene of the experimental case; the second one uses poplar as the roadside tree and plants them based on the real proportion; but in the third picture, emphasis on shape and color outweighs that on the appropriateness of roadside trees. Both the second and the third pictures are design schemes, and the third one is superior in aesthetic measure. However, this beautiful scene is infeasible locally, which

makes the second one the reasonable design.

Fig. 5

C. Designs of landscape "planes"

1) Design of protecting slope

In recent years, the design of freeway protecting slope has become an important part in landscape design, and

many related theoretical works have been published. This paper will not go into detail. However, to choose the optimum landscape design for the protecting slopes, we can analyze and evaluate the design alternatives based on the experimental method stated in this paper.

2) Design of rock wall

The experiment uses another freeway section of Chifeng City as the subject. Unique for the section, one side of the road is rock wall (See Figure-6 at left), open for beautiful fresco landscape. Actually, it is unusual for freeway to have rock walls as landscape. But in this case, it is the principal part of design. To paint an already designed picture on the rock wall is not difficult. Difficulty lies in how to determine the planar pattern and measure of the picture based on the visual changes of drivers or passengers, since static normal observation of the picture is different from the dynamic profile view from running vehicles.

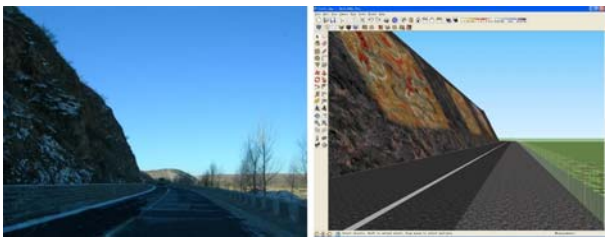

Fig. 6

Here we shall simulate a dynamic observation of the landscape and refer to the evaluation method of landscape "points" to create a scene model (See Figure-6 at right) with the aid of computer software: paint the planar picture on the rock wall, use picture size or spacing as single variables, divide the designs into several groups and make comprehensive analysis with the SD method. The conclusion is that to achieve the best visual effect of rock wall under fast running circumstances, the picture must be deformation treated based on its perspective principles before being painted. For example, to alleviate deformation, the "big when near and small when far" theory may be applied to have the picture "small when near and big when far" treated; or widen the picture or repeatedly show several pictures at a certain spacing to represent the continuity. The experimental figures closely related to drivers and passengers are:

TABLE I

Designed driving speed (km/h)	80	100	120
Visual angle of drivers or passengers (°)	30	20	12
Distance of attention concentration points (m)	300	420	540

With the reference to the functional relation of Figure-4, we use the 1km-section as the experimental subject, and can see that under the normal driving speed on freeways (usually about 100km/h), rock wall pictures simply flash by. Therefore, it is not recommended to paint a complicated picture for such a fleeting observation, because it is simply the waste of construction time and materials. Here we propose simple cultural symbols at the minimum spacing of 100m and the size of 1.5-2 times of normal plan view size (calculated based on the experimental figures in the above table and the Pythagorean proposition, and validated visually by the SD method). In addition, the pictures selected shall also reflect local cultures. In Figure-6, the picture is the lucky emblem originating from the ancient Yuan and Liao dynasties during which Inner Mongolia had a glorious history.

IV. Conclusion

With the aid of computer software, we can simulate the landscape of freeway; with the SD method, we bring forward following rational proposals for freeway landscape designs:

(i)Landscape design must not override highway construction standards and transportation rules. Function and safety must be given the first priorities. For example, the landscape design shall not be too flamboyant, otherwise it will distract drivers' attention.

(ii)Landscape materials must be durable and environmental friendly.

(iii)Take fully into account the psychological needs and visual demands of drivers and passengers.

(iv)Landscape designs shall be cultural and vivid, and strive for changes in the unification.

As a forceful validation of the research conclusion, the landscape design schemes of the cases referred in this paper are highly favored by the entrusting parties, and have been gradually executed. The cases of this study are from actual projects. Highlights lie in the vivid simulation of practical scenes with the aid of computer technology, the accurate and rapid analysis process, and the significance of the conclusions drawn. Surely, this research methodology still has room for improvement with the upgrade of software technology (so that more exquisite model may be created, or 3Dmax or Maya will be applied to produce more authentic and flamboyant simulation scenes), and the detailing of gradient grouping by experimental variables.

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