DEVELOPMENT OF SCENE EVALUATION AND DESIGN SYSTEM BY KANSEI DATABASE OF BRIDGE SCENE FOR AGREEMENT

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In this study, a system of scene evaluation and the computer-aided design of girder bridge is proposed for quick response in an agreement formation stage using XML which can also peruse the Internet using the analysis result by the sensitivity engineering technique of girder bridge. In addition, the example of a bridge and the display method of a score which agreed as a policy for supporting a scene design in the evaluation simulation and two or more design concepts accompanying category change were proposed. Moreover, in order to examine the usefulness of the built system, comparison with the example of a scene design of a real bridge was tried, and the validity of an output result was considered.

Key Words : girder bridges, kansei engineering, aesthetic assessment and design, kansei database

1. INTRODUCTION

In recent years, involvement of local residents in public works has been outstanding because more and more public attention has been paid to public works, and under severer financial conditions, a policy was put into place that public works should always meet the criteria whether it is really necessary for residents. Another trend of current public works is that expectation for infrastructure development has been rising which focuses on public-involved regional construction while making use of local characteristics and aesthetic feelings of residents. As a result, business models that appeal to residents’ involvement has been gaining popularity.

For citizen-involved development, opportunities such as public discussion meetings and workshops are often provided to gather opinions of people concerned. Construction plans presented at such public meetings are usually created by government officials or private designers, but in reality they do not always reflect diverse residents’ needs and their changing sense of value.

The reason why residents’ needs or sense of value are not reflected on construction plans is assumed to be as follows: (1) due to lack of understanding of diverse user needs, they do not think of good ideas to reflect user needs into design; and (2) due to lack of tools to reflect user needs into design, they cannot respond to the matters quickly, in other words, government officials or private designers cannot show design element changes and accompanying evaluation difference on the spot.

To cope with this problem, an approach has been attempted to create the following system: (1) the system that displays evaluation right after design element is partially changed; and (2) the system where one or more adjectives with weightings can be selected from design concept to realize it, outputting at the same time the sensitivity of design elements; the system displaying design elements that affect evaluation together with pictures of bridges.

The authors have paid attention to Kansei engineering techniques that have been already applied in fields such as product marketing. The authors have expanded Kansei engineering to girder bridges or arch bridges, analyzed the relationship between aesthetic feelings that students or bridge designers had and design component factors, and made research on its application1)-4).

The word Kansei here is explained as the action of human mind with which people intuitively gain a certain impression about outside stimuli5). In other words, it refers to a certain specific mind status.
holding emotions and images toward objects such as products and environments. According to Nagamachi\(^6\), Kansei engineering is the technology that stands between aesthetic feelings and engineering, a mechanism in which people’s aesthetic feelings are translated into product design elements from the engineering point of view.

Kansei database is the database that allows designers to easily access it on PC, and use Kansei evaluation system where adjectives, pictures, factor analysis results, scores obtained in accordance with Hayashi’s quantification theory (category I) are available. Fig.1 shows the configuration of the Kansei database. Girder bridges in the structure category and designers and students in subject category are studied in Fig.1. Collection of questionnaires for aesthetic feelings shown in Fig.1 is not dealt with in this research but planned via Internet for subjects with different attributes.

Target applications in the research using Kansei database are arch bridges and riverbank reinforcement. Shiraki et al.\(^2,3\) established Kansei database for arch bridge based on the questionnaire results and pictures, where comparison between average score and category score, and display of arch bridges that match the images described by adjectives are possible (scene display system). Similarly, Shiraki et al.\(^7\) created Kansei database for river scene in Shikoku region by conducting Kansei evaluation for citizens and river administrators there regarding their aesthetic feelings about riverbank reinforcement. These cases show that several Kansei databases have been created but in reality they have not reached the level of Kansei evaluation and design system yet, the level where they can be used effectively for planning and designing structures or facilities, or re-evaluating existing structures or facilities in daily design work.

Regarding the terminology, consensus building is a communication process taken when groups or members make a decision or take an action\(^9\). Through this process, they coordinate their opinions, cooperate one another, and take a give-and-take approach. The process of consensus building involves various aspects such as planning, plan evaluation, reviewing by making improvement, and operation control. Consensus is necessary in all of these aspects\(^8\).

Scene simulations using Virtual Reality Modeling Language (VRML), Geographic Information System (GIS) and Virtual Reality (VR) techniques are reported as major consensus-building techniques\(^9\)-\(^12\). Research was also conducted where Self-Organizing Map (SOM) was used to visualize the relationship between design elements and people’s aesthetic feelings\(^13\). In another research, a system was created to help create an alternative plan required for consensus building\(^4\). Similarly, a system was created in another research to reflect residents’ opinions and aesthetic favors in order to smoothly present alternative plans to the residents and assist their decision making\(^15\). These are the examples to indicate that tools have been developed such as scene simulation and those visualizing alternative plans and evaluation results conducted when the existing scene constituents are partially changed.

In this research, girder bridges were selected because they are the most common bridge in Japan and more often used as design plan for comparison. Analysis and evaluation are conducted regarding aesthetic feelings expressed by bridge designers who are actually involved in design work and residents who actually use it based on the Kansei engineering techniques, and incorporated into Kansei database. Using this database, attempt will be made to create Kansei evaluation and design system so that it can be used effectively for re-evaluating existing girder bridges and designing future girder bridges on a practical level. Through these steps, it is expected that citizen-involved infrastructure development considering residents’ needs is promoted effectively.

If Kansei database for civil structures and Kansei evaluation and design system can be put into practical use in this research, local residents can be actively
involved in decision-making process for structure design although conventionally only several government officials and engineers or designers were involved, and structure that matches residents' aesthetic feelings and thus they feel familiar to can be constructed.

2. BASIC CONCEPT OF DESIGN IN THIS RESEARCH

In this research, the base concept of design is based on reductionism, where nature or behavior of complex things are thought to be understood by reducing them into individual constituents and understanding each of them. It is pointed out that the process of reductionism tends to narrow down elements that are only apparent but neglect elements that are not, and therefore data will never be accumulated enough to understand the whole complex things.

There are two positions regarding design work; one is that design can be explained by reductionism and the other is that design cannot. In structural design, analysis and cross section definition is conducted for each element or cross section first, and then it is expanded to the whole. Here, the whole design is achieved only when total constraint conditions are carefully reviewed such as steel weight and relative stiffness. In scene design, first, girder color, main girder shape, substructure shape, etc. are examined to obtain better result in each item, but judgment is always made from the overall point of view because a change made on one element has no small effect on other elements. In other words, evaluation target is the final status after all the elements are combined. This means that relationship between elements must be understood all the time. It must be noted here that, unlike structural design, sum of optimal values of each element is not an optimal value as a whole.

In product design, as typified by Kansei engineering techniques, it is common to design each separate design element. On the contrary, in scene design for girder bridge, evaluation must be conducted from the overall point of view because sum of optimal values of each element may not be an optimal value as a whole. In the research where Kansei engineering techniques are applied to scene designing for girder bridge, reductionism has been proven a very important and effective evaluation method for girder bridge scene. According to reductionism, girder bridge is not evaluated just as it is but rather design elements are divided and evaluated according to separate items and categories so that a whole collection of civil structure or girder bridge even including background is evaluated.

According to Jingui's model of stimulation-impression-reaction shown in Fig. 2, the total impression of something like facility scene is formed by composite aesthetic feelings toward many stimulative physical attributes the facility has. This mechanism is called “impressing process”. Aesthetic status does not reflect the direct impression of the whole, but is the structure achieved by impressing process where several aesthetic feelings are collected.

The collective impression obtained through the impressing process is not recognized until it is converted to a specific expression. Once they recognize the impression, they react. This process is called “reacting process”. The process enclosed by a dotted line in Fig. 2 indicates one’s internal process that is unconsciously prosecuted.

Feelings toward aesthetic status of the facility scene are expressed based on aesthetic information and it is obtained through one’s perception and cognition processes. More often, adjectives called Kansei (aesthetic) words are used to describe the feelings. Therefore, using the evaluation results by Semantic Differential (SD) method where adjective pairs are used, scaling is performed according to the method adopted in quantitative psychology (such as paired comparison method and successive category method) and semantic structure described by the adjectives are clarified by various multivariate analysis techniques (such as correlation analysis, regression analysis, principal component analysis and factor analysis) to obtain related aesthetic information.

However, some cautions must be taken: (1) the aesthetic information thus obtained is unstable or cannot always be reproduced because it is based on cognition result of a person; (2) meaning may become unclear because it inevitably requires value judgment (evaluation); and (3) there is no common description method that expresses all types of scene phenomena.

In this research, based on the concept mentioned above, although reductionism is the prerequisite, evaluation and checking must be conducted from the overall point of view because sum of optimal values of each element is not an optimal value as a whole. In this research, evaluation as a whole is conducted by
checking conformance with design concept and several adjectives converted from the design concept.

3. QUESTIONNAIRE SURVEY FOR AESTHETIC FEELINGS

(1) Experiment method

The 5-scale Semantic Differential (SD) scaling was used for questionnaire survey. The SD method is said to be a fully objective, reliable, reasonable and sensitive measurement method and applicable for various fields where subjects and concepts are diverse.

(2) Subjects

The subjects were 40 students composed of freshmen and senior of Civil Engineering Major, Faculty of Engineering, Kansai University and 15 bridge designers. Breakdown of the students is 20 male students and 20 female students. At this research stage, subjects were selected only from specific categories although it is important that subjects are actual users but they can also be categorized by age, sex, professions, residence etc.

(3) Evaluation target and pictures

Pictures were used expediently as evaluation target since it has been proven already that one feels similarly toward pictures as when seeing an actual thing, although most ideal target is the actual girder bridge.

Totally 90 pictures of girder bridge were selected from a magazine titled "Bridge Annals" because it is necessary to select pictures that are easier for the subjects to judge and easier to understand what is photographed, and whose entire layout is well balanced. There are some drawbacks of Kyoryo Nennkan from the viewpoint of pictures for evaluation or design study because there are various view points. Therefore, pictures were selected as much as possible first and from them only those with well-balanced variations such as girder color, substructure and surrounding scene were selected (90 pictures in total). Further, the pictures were processed into larger (A4, horizontal) size for evaluation which is easiest to see for the subjects. According to the quantification theory, a total number of samples must be larger than the sum of explanatory variable to obtain statistically meaningful results. In order to quantify explanatory variable that is non-metric data, a sum of explanatory variable is not a sum of items but a sum of categories. In the examples used in this research, the sum of categories is 60 and the number of samples is 90 which is larger than the number of categories, as later described in Section 4.

In this research, pictures with various layouts and view points were used. Most of users’ view points in actual cases are limited, and thus pictures taken from a view point that is really unfamiliar to users affect evaluation result. Therefore, through this research, analysis via questionnaire survey was conducted using the pictures taken not only from limited view points familiar to the users but also from all other view points. By doing so, the impact of layout and view point on evaluation can be understood quantitatively.

The document describes the influence of view point on evaluation by changing it on the same girder bridge. The result shows that the evaluation score varies within a range from -2.0 to +2.0 (1.8 max.) when the view point changes, although the range varies according to adjectives. More specifically, partial correlation coefficient was used in this research to indicate the influence of view point on evaluation according to adjectives based on the analysis result obtained by the quantification theory.

![Fig.3 Questionnaire](image-url)
(category I) mentioned later. By using scores by adjectives describing image calculated by the quantification theory (category I), it is possible to know the change width of category in each item that affects evaluation advantageously or disadvantageously and thus use it effectively for scene design work.

(4) Aesthetic words
Forty three adjective pairs were used as those describing images of girder scene. Fig.3 shows the actual SD questionnaire slip.

(5) Experiment method
Creative method was used in this questionnaire

| Item | Category | Partial correlation coefficient | Range | Score |
|------|----------|-------------------------------|-------|-------|
| 1. Plan view | uniform | 0.0323 | 0.0059 | 0.0193 |
| | transform | 0.0252 | 0.0193 | 0.0323 |
| 2. Shape of main girders | straight | 0.1805 | 0.0320 | 0.1478 |
| | curved | -0.1478 | 0.1805 | 0.0320 |
| 3. Color of Girders | red | 0.2103 | -0.0736 | 0.0402 |
| | blue | -0.0375 | -0.0402 | 0.1805 |
| | ivory | 0.2525 | -0.0736 | 0.0402 |
| | gray | -0.0110 | 0.2525 | -0.0736 |
| | green | -0.0375 | 0.2525 | -0.0736 |
| 4. Color of balustrades | gray | 0.3749 | -0.2061 | 0.1407 |
| | brown | -0.2061 | 0.3749 | -0.2061 |
| | white | 0.1407 | -0.2061 | 0.3749 |
| | green | -0.0470 | 0.1407 | -0.2061 |
| 5. Shapes of substructures | steepening | 0.2566 | -0.0294 | 0.1285 |
| | columnar | 0.1285 | -0.0294 | 0.2566 |
| | rectangle | 0.0135 | 0.1285 | -0.0294 |
| | inverted trapezoid | -0.2861 | 0.0135 | -0.0294 |
| 6. Sectional forms of substructures | circular | 0.3568 | 0.2298 | -0.1940 |
| | block-triangular | -0.1940 | 0.3568 | 0.2298 |
| | oval | 0.0279 | -0.1940 | 0.3568 |
| 7. Number of piers | 1 | 0.2448 | -0.1673 | 0.1216 |
| | 2 | 0.1216 | -0.1673 | 0.2448 |
| | 3 | 0.1320 | 0.1216 | -0.1673 |
| | 4 | 0.0972 | 0.1320 | -0.1673 |
| | 5 more | -0.0470 | 0.0972 | 0.1320 |
| 8. Type of balustrades | wall | 0.2821 | 0.1981 | -0.0551 |
| | longitudinal sash | 0.1981 | -0.0551 | 0.2821 |
| | transversal sash | -0.0551 | 0.1981 | 0.2821 |
| 9. Drain pipes | exist | 0.3110 | -0.1307 | 0.0871 |
| | nil | 0.0871 | 0.3110 | -0.1307 |
| 10. Lighting posts | exist | 0.0362 | 0.0086 | -0.0213 |
| | nil | -0.0213 | 0.0362 | 0.0086 |
| 11. Inspection passage & other accessory structures | exist | 0.0836 | -0.0604 | 0.0124 |
| | nil | 0.0124 | -0.0604 | 0.0836 |
| 12. Sight distance | close | 0.4237 | 0.1336 | 0.1913 |
| | middle distant | 0.1913 | -0.1336 | 0.4237 |
| | far | -0.1336 | 0.1913 | 0.4237 |
| 13. Angle of incidence | lateral | 0.2078 | -0.2878 | 0.0243 |
| | oblique | 0.0243 | -0.2878 | 0.2078 |
| | upper | -0.2878 | 0.0243 | 0.2078 |
| | horizontal | -0.0784 | -0.2878 | 0.2078 |
| | lower | 0.2078 | -0.0784 | 0.0243 |
| 14. Height of viewpoint | mountain | 0.3846 | 0.3306 | 0.1552 |
| | hill | 0.1552 | 0.3846 | 0.3306 |
| | river | 0.3306 | 0.1552 | 0.3846 |
| | white | 0.1711 | 0.3306 | 0.1552 |
| | green | 0.1552 | 0.1711 | 0.3306 |
| | blue | -0.0784 | 0.1552 | 0.3306 |
| 15. Scenery | mountain | 0.3846 | 0.3306 | 0.1552 |
| | hill | 0.1552 | 0.3846 | 0.3306 |
| | river | 0.3306 | 0.1552 | 0.3846 |
| | white | 0.1711 | 0.3306 | 0.1552 |
| | green | 0.1552 | 0.1711 | 0.3306 |
| | blue | -0.0784 | 0.1552 | 0.3306 |
| 16. Color of upper background | green | 0.4136 | -0.0938 | -0.0300 |
| | black-brown | -0.0300 | -0.0938 | 0.4136 |
| | blue | 0.4078 | -0.0300 | -0.0938 |
| | gray-white | -0.0118 | 0.4078 | -0.0300 |
| 17. Colors of lower background | large | 0.0310 | 0.0236 | 0.0060 |
| | middle | 0.0060 | 0.0236 | 0.0310 |
| | small | 0.0310 | 0.0236 | 0.0060 |
| 18. Clearance | exist | 0.1014 | -0.0732 | 0.0154 |
| | nil | 0.0154 | -0.0732 | 0.1014 |
| 19. Parallel bridge | exist | 0.2872 | -0.1355 | 0.0784 |
| | nil | 0.0784 | -0.1355 | 0.2872 |

Fig.4 The result of quantification theory (category I) for bridge engineer.
survey because there were relatively a large number of pictures and evaluation items. The pictures were placed on the tables in the lecture room, and the subjects were encouraged to freely walk around the table and fill in the questionnaire at their own pace. Much consideration was given to their pace of filling in the questionnaire because long-lasting questionnaire survey is expected to make them tired and affect evaluation. They were allowed to take a rest whenever they felt tired and there was no time limit. After the survey, the subjects were asked: a) what specific points of pictures they checked (color, shape, etc.); b) their evaluation criteria (beautiful, focus on shape, etc.); and c) what adjectives were difficult to judge (evaluate) to examine the accuracy of the evaluation.

4. ANALYSIS BY KANSEI EVALUATION

The questionnaire result was used for creating SD profile and analyzed according to the factor analysis and quantification theory (category I). The analysis result using the quantification theory (category I) to study the combination of aesthetic words used in Kansei database and design elements is explained in the following sections.

(1) Combination of aesthetic words and design elements

The quantification theory (category I) is used to explain external reference value quantitatively measured based on qualitative factor information. Design elements that seem to have a great impact on bridge scene were selected, and effect of the design elements on each adjective describing image (aesthetic words) was analyzed by the quantification theory (category I).

a) Items/categories table

For analysis by the quantification theory (category I), items/categories table must be created first. Items here refer to the matters regarding design elements that affect girder bridge scene such as bridge type, bridge color, background and substructure. Categories refer to further classification of each design element, for instance, tapered T-beam type or wall type in the case of substructure. Therefore, items that seem to affect girder bridge scene and their categories were selected to create a table. This table classifies each picture of girder bridge into elements, which will be used as input data for analysis by the quantification theory (category I). Fig.4 shows the items(categories) table.

b) Analysis by quantification theory (category I)

To clarify the relationship between the items/categories table created as mentioned above and adjectives describing image, average evaluation value was used as input data for each picture and analyzed using the quantification theory (category I) regarding all the 43 adjective pairs for each subject. Fig. 4 shows the analysis result by the quantification theory (category I) regarding “Beautiful” evaluated by a bridge designer. The score was represented in histogram on the right side in Fig.4.

(2) Possibility of item change

In this research, view point, background element, girder shape, dimension, color, etc. are handled at the same level to quantitatively understand factors that affect evaluation except design elements of the bridge such as layout and view point.

In bridge scene design, items such as view point, background, background color, presence of existing bridge and obstacles are normally considered unchanged or given conditions. Categories belonging to these items are supposed to be almost determined before studying bridge design elements such as girder shape and color, handrail, substructure because in the design process construction points are determined first. Therefore, changeable items and unchangeable items are classified. For example, regarding the 20 items shown in Fig.4, items from no. 1 to 11 are design elements of the bridge itself and thus changeable when designing scene, and items from no. 12 to 20 are the items provided as given conditions such as background. It is assumed that it depends on the situation where the system is used whether these items are considered equivalent. In other words, at detailed design stage when background is already unchanged, only bridge design elements can be considered. However, at maintenance and control stage when background of construction points is changed or when studying what impact is given on evaluation when view points are changed, background elements must also be considered. In the existing research1,2,4 too, it is pointed out that scores obtained by quantifying view point, background, background color, presence of existing bridge or obstacles are unignorable.

The purpose of this research is to establish a system to assist consensus building at plan designing stage and maintenance and control stage. The first function of the system is to simulate evaluation according to category change a), and it checks how evaluation changes when bridge design element is changed, and it may be used both at plan designing stage and maintenance and control stage. At plan designing stage, view point and background must be fixed because it is expected that background elements are hardly changed. However, if it is the case that impact of changing view point on evaluation wants to be clarified, evaluation result is obtained by changing
conditions of view point. The purpose of changing view point is to search another possible view points that lead to better evaluation result. On the other hand, presence of existing bridge or obstacles is unchangeable condition.

Regarding the function that simulates evaluation according to category change a) above, the following issues arise among the 20 items shown in Fig.4 when considering items from no. 1 to 11 are design elements of the bridge itself and thus changeable when designing scene, and items from no. 12 to 20 are the items provided as given conditions such as background.

- It is impossible to see evaluation difference according to view point. A tool for study is necessary such as when determining one view point among many that has the best evaluation or when searching another view point if the predetermined one is not evaluated well, although the view point is the basic condition to be set at the first stage of scene design.
- If items such as background must be fixed, bridge data equivalent to all the combinations of items no. 12 to 20 (13,824 categories) must be prepared, which is unrealistic.
- In the function that simulates evaluation according to category change a), although background element is fixed, if these background items are excluded, background conditions must be specified separately because changes in background conditions (such as view point and background) give large amount of influence on evaluation1)4). If background conditions must be specified, it will be more convenient for users if they can change background conditions in the simulation.

For this reason, all the items from no. 1 to 20 are used for the function that simulates evaluation according to category change a).

Another function b) of displaying bridges that conform to the design concept can be used at plan designing stage. At plan designing stage, alternative plans can be created that concerned people desire if design elements that conform to the design concept are known. At maintenance and control stage, it is quite conceivable that when time passes, bridge becomes unable to conform to the design concept due to changes of residents’ needs, sense of value, ambient environment etc. If it is the case, there are two possible actions to take: define design concept again or re-study background elements. However, because changes in background element has nothing to do with bridge scene design, background element needs to be considered as given condition if design concept is not changed. Then, simulation is necessary while background element is fixed. In this case, such specification is required that background conditions are input at the same time when selecting the design concept, because, as mentioned above, if view point or background is fixed, the required bridge data will be too much and nothing can be done against changes of view point or background element.

The existing research1)-4) also mentions that view point and background have a large impact on evaluation and thus it is highly expected that un-matching occurs between simulation and actual evaluation if bridge that conforms to the design concept and items/categories that affect evaluation are calculated while disregarding view point and background element. In this research, view point and background must be considered as a part of design element, and it is worthwhile to do so actively if evaluation may become better by slightly changing background or view point at time of future maintenance or redesigning, etc.

5. ESTABLISHMENT OF SUPPORT SYSTEM USING KANSEI DATABASE

(1) Procedure
a) Evaluation simulation according to category change

Evaluation simulation according to category change is required at detailed design stage and maintenance and control stage. At detailed design stage, trial-and-error approach must be taken while determining design to see what changes of design element affects evaluation how much. Evaluation simulation according to category change is useful for such occasion. By selecting applicable category by items, the score of adjective describing image in need can be obtained immediately. Changes frequently occur while proceeding detailed designing, and re-evaluation often needs to be conducted when category is partially changed whether it is plan designing stage or maintenance and control stage. Using this simulation, however, one can immediately know whether the change has a good effect or not. Since civil structures last very long, say several decades after construction, as time passes, the ambient environment changes and it will happen that the structure that was harmonious with, for instance, ambient environment at designing stage becomes unable to conform to the design concept that was originally intended. As several decades pass, structure redesign is necessary at appropriate timing because otherwise it will fail to respond to expected changes of residents’ needs and sense of value, and to conform to the design concept that was originally set. Then, the evaluation simulation according to cate-
The calculation procedure for the evaluation simulation according to category change is explained as follows. First, subject is selected (1. female students; 2: male students; 3: bridge designers). Second, category (totally 60) is selected by items (1 to 20). For instance, as underlined in Fig.5 showing evaluation flow chart upon category change, each item is selected like this: main girder has variable cross section, horizontal alignment is straight, girder color is blue, and there are no obstacles. Then, in accordance with Equation (1), a category selected by adjectives is multiplied by score:

$$\text{sum}(i) = \sum_{j=1}^{43} \text{score}(i,j) \times \text{sel\_category}(j) \quad (1)$$

where,
- \(\text{sum}(i)\): total score of each adjective (\(i=1\) to 43)
- \(\text{score}(i,j)\): category score of each subject calculated by quantification theory (category I) (\(i=1\) to 43, \(j=1\) to 60) or score of selected category \(j\) of item \(i\)
- \(\text{sel\_category}(j)\): selected category (\(j=1\) to 60) (1 or 0)

b) Display of bridges and score that conform to design concept

The design concept to be determined at planning stage is important element that forms the foundation of scene design. However, it is not easy to propose a bridge design draft that conforms to the design concept. For instance, it is difficult to create a draft that satisfies the three concepts “beautiful”, “harmonious” and “locally rooted” if there are no tools that help determine necessary design elements to create alternative plans. Studies need to be conducted under various conditions such as what the result is when the subject is changed or when weighting of the concept “locally rooted” is doubled. To respond to such various conditions, if it is possible to set multiple design concepts with weightings and display category score, design elements can be determined by referring to the category whose score is high. Further, if it is possible to calculate total value of category obtained from the established multiple design concepts according to bridge, and display bridges in
descending or ascending order of the category total value, alternative plan can be created while referring to bridges that conform to the multiple design concepts. In other words, alternative plans can be created while referring to not only highly scored items/categories but also pictures of actual bridges. Further, by displaying bridges in descending or ascending order, reference to both bridges that conform to the design concept well and those not much in parallel. Shortly, one can refer to bad examples as well as good examples. Referring to bad examples is crucial and effective because it is the minimum requisite that bridge that does not conform to the design concept should not be built.

The calculation procedure is as follows. Subject is selected (1. female students; 2: male students; 3: bridge designers). Then design concept is established with weighting, for instance, beautiful (weighting=1), harmonious (weighting=1) and locally rooted (weighting=2). Then, selected concept multiplied by category score is calculated using Equation (2):

\[
item\_sum(i) = \sum_{j=1}^{43} score(j,i) \times sel\_keiyoshi(j) \quad (2)
\]

where,
- \(item\_sum(i)\): total concept weighting \((i=1\ to\ 60)\)
- \(score(j,i)\): category score of each subject calculated by quantification theory (category I) \((j=1\ to\ 43, i=1\ to\ 60)\) or score of selected category \(j\) of item \(i\)
- \(sel\_category(j)\): selected concept weighting \((j=1\ to\ 43)\)

Then, bridge basic data (items/categories classification) is multiplied by total concept weighting calculated using Equation (2) to obtain total score:

\[
score\_sum(i) = \sum_{k=1}^{60} item\_sum(k) \times bridge(i,k) \quad (3)
\]

where,
- \(score\_sum(i)\): total score of each bridge \((i=1\ to\ 90)\)
- \(bridge(i,k)\): bridge basic data classified by items/categories \((i=1\ to\ 90, k=1\ to\ 60)\)

Finally, based on the total score calculated by bridge, bridges are listed in descending or ascending order.

Fig.6 shows the flow chart from concept selection to score and bridge display.

(2) Database configuration

Fig.7 shows the configuration of the Kansei database created in this research. Designers use the database to search for aesthetic words (adjectives describing images) regarding the bridge they start planning and designing. As a result, images, SD profiles, several most highly ranked and poorly ranked bridges according to category score and the questionnaire result are displayed on the screen. So, designers can proceed design work based on this search result. The functional outline of the database is explained as follows.

a) Girder bridge scene database

Basic specifications of 90 girder bridges collected (such as girder bridge name, main girder cross section, horizontal alignment, color and picture) are
retrievable in this database, and applicable bridges are displayed upon selection of items/categories. More specifically, basic bridge data is displayed (2 types: category is displayed according to item or presence of data is displayed according to category) and bridge according to items/categories can be searched. The basic bridge specifications, which are items/categories analyzed by the quantification theory (category I), are selected as explained below. For instance, nominal scale with a specific rating is used when main girder cross section is selected as either constant or variable, and horizontal alignment is selected as either straight or curved. The items/categories were selected by selecting design elements that are used to convert the concept into precise design elements, and the design elements that are minimum required for design were selected as items while referring to bridge designers’ opinions and past design cases. Here, span/pier height ratio was not taken into consideration because ideal span/pier height ratio cannot always be achieved due to constraint conditions, although it is often used as design standard and seems to be effective.

b) Analysis result database
When subject and adjectives are selected, quantification analysis result is displayed. To be more specific, quantification analysis result for each subject (multiple correlation coefficient, partial correlation coefficient, range, and score for 43 adjective pairs) can be displayed, as well as list by subject.

c) Scene evaluation according to design element change
Scene evaluation result according to partial design element change (items/categories) is displayed for each evaluation target.

d) Scene evaluation by concept selection
Applicable bridges are displayed in the order of score by selecting multiple design concepts by subject.

(3) Database display example
The created Kansei database has various functions. Display examples of scene evaluation according to design element change and concept selection are as follows.

a) Scene evaluation according to design element change
Scene evaluation result according to partial design element change (items/categories) is displayed for each evaluation target. Fig.8 shows the example where female student was selected and category was selected for each item. Score for each adjective from no.1 to 43 is displayed as shown in Fig.9. In this way, evaluation can be conducted immediately when design element is partially changed.

b) Scene evaluation by concept selection
Applicable bridges are displayed in the order of score by selecting multiple design concepts by subject.

After input is completed, category score is calculated based on the selected multiple adjectives which describe image and their weightings, and several bridges that are most highly ranked and poorly ranked in the order of total category score, respectively, are displayed. Designers can refer to this
output example and immediately grasp design features of highly ranked bridges and poorly ranked bridges.

60 category scores calculated regarding 20 items from selected adjective describing image are also displayed with a list of applicable pictures. It is distinctive that design features that conform to the multiple design concepts can be checked also by referring to the applicable category score. For instance, one can know that the score is higher when the main girder has variable cross section and girder color is green. The characteristic of this system is that bridges with high category scores and those with low category scores are both displayed and thus comparable to understand design features more clearly.

Fig.10 shows the screen to select design concept. Subject is female student and “cool (+1)”, “beautiful (+2)” and “sophisticated (+1)” were selected. The values in the parentheses are the weightings. Fig.11 shows an example where each total category score is calculated from the input adjective and weighting. Totally 60 category scores are displayed varying from main girder cross section and girder color is green. The characteristic of this system is that bridges with high category scores and poorly ranked bridges are shown, although poorly ranked bridges can also be shown.

6. VERIFICATION AND STUDY

The system established in this research was applied to the actual bridge scene design and studies have been conducted to check system validation and how to reflect the output result on design.

(1) Bridge specifications

Table 1 shows the bridge specifications for verification.

| Bridge name | bridge K |
|-------------|-----------|
| construction point | osaka prefecture |
| Road standard | 3-3 |
| Design speed | /=50km/h |
| class of bridge | first class bridge(TL-20) |
| bridge length | 230.000m |
| type of super structure | 4 span continuous girder bridge |
| type of sub structure | wall type |
| span length(m) | 29.20+2@29.60+29.20+27.40+3@27.80 |
| bridge width | car:16.0-13.0m, pede:3.0m |
| skew angle | A1:82.5°, a2:71.0°, P1-P7:76.5° |
| Cross slope | car:1.5%, pede:2.0% |
| profile slope | 1.44%-1.779%-0.34% |
| specification of highway bridges | specification of highway bridges(1990.2.) |

Table 1 Bridge specifications for verification.

(2) Conversion from concept to design elements

Scene concept introduced from the basic idea is often described in phrases like “fusion or unity with countryside” as in the case of Bridge K. The concept is backed by the basic idea and related with history and ambient environment. As primary adjectives describing image of Bridge K, words used in the basic idea and scene concept were converted into 43 adjectives already given. For example, the word countryside was converted to “urban”, unity with ambient environment to “merged into background”, and fusion to “harmonious”.

The selected 43 adjectives describing image are
frequently used design concepts with reference to the past scene design cases.

Three specific primary adjectives describing image, “harmonious (+1)”, “merged into background (+1)”, and “urban (-1)” were determined from the design concept. The values in the parentheses are the weightings. The adjective urban has a negative weighting because urban is the completely opposite image of countryside in the concept. Furthermore, image described as “shape with good force flow” was determined upon the discussion among ordering and ordered companies, and thus the following secondary adjectives describing the image of shape with good force flow were determined, “neat (0.5)”, “balanced (0.5)” and “dynamic (0.5)”. All these adjectives have a weighting of 0.5 or a half of that of primary adjective weightings. The adjective urban has a negative weighting whether cross section is constant or variable. From the result shown in Table 3, changes of design elements and their evaluation differences can be known by subject.

| Plan view | Shape of main girders | Color of Girders | Color of balustrades | Shapes of substructures | Sectional forms of substructures |
|-----------|----------------------|----------------|----------------------|-------------------------|--------------------------------|
| uniform | straight | blue | brown | enhancing | circular |
| -0.114748 | 0.0315452 | 0.0846316 | 0.6212921 | 0.2857782 |
| 0.0060429 | 0.094976 | 0.3772984 | 0.7948962 | -0.3159942 |
| 0.0118455 | 0.0557181 | 0.3772984 | 0.7948962 | -0.3159942 |
| 0.0060429 | 0.094976 | 0.3772984 | 0.7948962 | -0.3159942 |

Table 3 shows the category/score that conforms to the adjectives describing image by subject, the output after the six adjectives and their weightings were input in the system. The items/categories to which Bridge K under study conforms are marked with a circle “○” in the Bridge K column. The items/categories with “□” are the result of the final plan, although there were various plans presented at the study stage. The values in Italics are the categories with the highest score in each item.

| Item | Category | Female students | Male students | Bridge engineer | Bridge K |
|------|----------|----------------|--------------|----------------|--------|
| Plan view | uniform | -0.114748 | 0.0060429 | 0.0118455 | ○ |
| | transform | 0.0315452 | 0.094976 | 0.0557181 | ○ |
| Shape of main girders | straight | 0.0315452 | 0.094976 | 0.0557181 | ○ |
| | curved | -0.0174599 | 0.2301772 | -0.2642638 | ○ |
| Color of Girders | red | -0.3149846 | -0.3946784 | -0.2664561 | ○ |
| | blue | 0.3046316 | 0.3772984 | 0.3772984 | ○ |
| Color of balustrades | gray | -0.386221 | -0.4861602 | 0.14581935 | ○ |
| | brown | 0.6212921 | 0.7948962 | 0.7948962 | ○ |
| Shapes of substructures | enhancing | 0.2857782 | -0.3159942 | -0.3159942 | ○ |
| | columnar | -0.2183343 | 0.1277294 | 0.4117675 | ○ |
| Sectional forms of substructures | rectangular | -0.3637356 | -0.3531878 | -0.1373378 | ○ |
| | inverted | 0.1710026 | -0.5802722 | -0.743533 | ○ |
| | oval | 0.2482985 | 0.3024541 | 0.3798454 | ○ |
| Number of piers | 1 | -0.9447449 | -0.1408992 | -0.3605157 | ○ |
| | 2 | -0.0875231 | -0.0757629 | -0.1359601 | ○ |
| | 3 | 0.3906727 | 0.3179301 | 0.3204064 | ○ |
| | 4 | -0.1957989 | 0.352294 | 0.4970038 | ○ |
| Type of substructures | 5 more | 0.1951367 | -0.2703185 | -0.1362638 | ○ |
| Drain pipes | wall | -0.427971 | -0.1870962 | 0.5658345 | ○ |
| Lighting posts | / | 0.1612368 | 0.1403233 | 0.1403233 | ○ |
| | / | 0.0409596 | 0.2046365 | -0.1725039 | ○ |
| | Bridge | 0.0326479 | 0.1122762 | 0.5062762 | ○ |
| | / | -0.0169868 | 0.1851775 | -0.3605157 | ○ |
| | / | 0.0097948 | -0.526273 | -0.3605157 | ○ |
| | / | 0.1172475 | 0.0654111 | 0.3605157 | ○ |
| | / | -0.0113831 | -0.0047322 | -0.0047322 | ○ |
| | / | -0.1368471 | -0.4296212 | -0.4296212 | ○ |
| Light absorbent | / | 0.1209561 | 0.5889982 | 0.433653 | ○ |
| | / | 0.3796777 | 0.2906786 | -0.3562951 | ○ |
| | / | -0.4113474 | -0.6174354 | -0.1444371 | ○ |
| | / | 0.8050324 | 0.4668699 | 0.5384349 | ○ |
| | / | 0.0482416 | 0.0857526 | 0.29896392 | ○ |
| | / | -0.4377203 | -0.319982 | -0.105331 | ○ |
| | / | 0.3888805 | 0.0555751 | -0.1404193 | ○ |
| | / | 0.1393019 | -0.1568676 | 0.4011922 | ○ |
| | / | -0.1697942 | 0.0475116 | -0.1181261 | ○ |
| | / | 0.0190583 | -0.1129086 | 0.21704046 | ○ |
| | / | -0.0324645 | 0.0141803 | -0.1301063 | ○ |
| | / | 0.0061551 | 0.338231 | -0.0854341 | ○ |
| | / | 0.0370165 | 0.8597806 | 0.1030457 | ○ |

Table 3 shows sensitivity of each item/category on the adjective describing image. The subjects had different opinions about girder bridge color. The total score of green is high for female and male students, while that of ivory is high for male students and bridge designers, but that of yellow is high for both male and female students. It is desirable to carry out comparative study separately when evaluation differs depending on the subject, which is the actual case in Bridge K.
by Osaka Prefecture and area classification at construction points, four colors, grayish pink, yellowish ivory, grayish green, light gray blue were selected. Then color perspective drawing was created to show influential people and other people involved, and finally light gray blue was selected. The color category is red, blue, ivory, brown, gray and green as shown in Table 3 and there cannot be too many classifications due to data amount limitations. Therefore, grayish green, the mixed two colors, is classified as green. If pink is classified as red, the selected four colors all fall in the six categories in Table 3. When blue was selected by the ordering company, since there is no subject classification of ordering company in this system, adding analysis result via questionnaire survey etc. will be a future task. At time of repainting, evaluation by all the subjects can be better when the color is changed to green, because average value for green is highest.

A lot of design elements are determined by Cabinet Order concerning Structural Standards for River Management Facilities and other restrictions, but it is true that some design elements are divisive among subjects. It is expected that decision-making upon consensus building is made efficiently if alternative plans are created with reference to the design element that is highly evaluated by each subject, particularly actual user, and that higher evaluation is achieved also after completion. Elaboration only in specific portions does not suffice, but the entire balance is also important. Pictures of bridges with higher total score of the selected design elements will be helpful to get hold of the entire image.

Score is calculated from the adjectives mentioned in Section 6, and applicable bridge pictures are listed in descending order of score as shown in Fig.12 for example. The list is displayed for each subject. In this list, categories with weightings that affect the total score are displayed, as well as the categories that negatively affect the total score. Of course, it is possible to understand score sensitivity of each subject by referring to Table 3, but it will be much easier to create alternative plans if designers can look at actual pictures that conform to the conditions (concepts) and understand factors that affect evaluation.

(3) Evaluation according to design element change

When the design stage proceeds to study stage for detailed bridge structure, it is necessary to understand how evaluation changes when each design element is changed to create a comparison plan. The design elements of Bridge K shown in Table 3 are input in the system and the evaluation was conducted. Table 4 shows the result of evaluation for each adjective according to subject when girder color is changed.

Table 4 Result of evaluation for each adjective according to subject when girder color is changed.

| No | Image       | Color of girder | score by table3 | estimation by table4 |
|----|-------------|-----------------|-----------------|---------------------|
| 8  | urban       | red -0.11      | -0.45           | -0.76               |
| 9  | merged into background | 0.337     | 0.465           | 0.652               |
| 10 | harmonious  | 0.286          | 0.562           | 0.434               |
| 11 | light      | 0.207          | 0.292           | 0.29                |
| 12 | balanced   | 0.224          | 0.357           | 0.423               |
| 13 | dynamic    | -0.3           | -0.37           | -0.335              |

Note: (-8+13+41)*1+(14+17+42)*0.5

Table 5 Comparison was made to the score that conformed to the six adjectives describing image obtained in Table 3.

| female students | Color of girder | score by table3 | estimation by table4 |
|-----------------|-----------------|-----------------|---------------------|
| blue            | 0.03463616      | 3               | 1.2756483           |
| ivory           | 0.4607486       | 2               | 1.734058            |
| brown           | 0.03463616      | 3               | 1.2756483           |
| gray            | -0.2862216      | 6               | 2.8272503           |
| green           | 0.62129111      | 1               | 2.0550122           |
| red             | -0.3964784      | 5               | 0.6783336           |
| blue            | -0.0076685      | 3               | 0.5884155           |
| ivory           | 0.19877145      | 2               | 0.9764373           |
| brown           | -0.2130568      | 4               | 0.609038            |
| gray            | -0.4861606      | 6               | 2.7285841           |
| green           | 0.79489626      | 2               | 1.4597907           |
| red             | -0.2694671      | 6               | 2.1692036           |
| blue            | 0.048890845     | 5               | 2.8511411           |
| ivory           | 0.17577416      | 1               | 0.7240824           |
| brown           | 0.11309492      | 4               | 0.7438944           |
| gray            | 0.14585353      | 1               | 0.2754028           |
| green           | 0.1097635       | 4               | 0.515481            |

According to Table 4, regarding the six adjectives selected in Table 2, the sum of evaluation values with weighting was calculated according to subject, where the evaluation value obtained when the girder color was changed was multiplied by weighting. Then comparison was made to the score that conformed to the six adjectives describing image obtained in Table 3, and the result is shown in Table 5. According to the comparison result, the score obtained in Table 3 and sum of evaluation value do not match, but their order (sensitivity) is substantially equal, indicating that the evaluation according to design element change is appropriate.

When design concept has already been set and converted to adjectives describing image, evaluation according to design element change can be checked up to sensitivity by referring to the score list in Table 3 showing conformance to the adjectives describing image according to subject. In short, the total score
value (evaluation value) increases when the present girder color of blue is changed to green. This can be confirmed by the girder color column in Table 3 and the sum of weighting for the selected adjective in Table 4. When using the average of the three subjects, color change from present blue to green, ivory or brown may be another choice. The reason of the low evaluation value for “dynamic” is probably because the setting of higher view point for Bridge K results in lower evaluation, compared to the high score when view point is lower. Table 4 shows that the score for dynamic increases when the girder color is gray. However, if it is the case, the score for “urban” decreases although for dynamic increases, resulting in the total weighting for the selected adjective decreasing from 1.2439 to 1.13.

There is one-step advanced use of the system. When several decades have passed after a bridge was put in service, it is expected that ambient environment drastically changed and does not conform to the original design concept. It is often the case that the original area was developed as countryside area but experienced urbanization due to zoning change and accelerated residential development. In this case, it may happen that the original weighting for the adjective urban –1 is changed to +1. Then gray for girder color will be selected from Table 4.

In the case of girder bridge, changes rarely occur in main girder cross section, horizontal alignment, number of beams, drainage pipes, inspection path, attached facilities, visual distance, viewing point height, angle of incidence, clearances, etc. Considering design concept change accompanied by drastic ambient environment change as natural, it is possible to select adjectives from Table 4 first that will lead to higher evaluation and then determine the design concept.

For girder bridges, the existing research shows that scene element of bridge deck has a large impact on adjective describing image. However, in this research, there is no classification among design handrail, newel post, monument, bridge head plaza, design illumination, pavement color, sidewalk pavement type, etc. Handling of this variety remains as a future issue.

7. VALIDATION OF USEFULNESS AND EFFECT

(1) Questionnaire to bridge designers and students

The questionnaire survey was conducted for Kansei evaluation and database functions regarding scene evaluation and design support system using the Kansei database established in this research. The questionnaire was answered by engineers from a bridge maker or consulting company who are actually involved in bridge planning or design work or engineers who have experienced consensus-building jobs in a consulting company, and students from the faculty of engineering. There were two types of questionnaire: one for aesthetic feelings and the other for database functions. The subjects were composed of 10 engineers from consulting company, 15 engineers from bridge maker, 21 male students, and 22 female students.

The first questionnaire survey was conducted by showing the subjects the pictures of Bridge K after construction as mentioned in Section 5 above and asking them to fill in the questionnaire described in (2) below. The pictures of Bridge K are two: close view and intermediate view, each photographed from the right and left sides of the river bank. The other questionnaire for the database function was conducted by actually loading the scene evaluation and design support system on the server and examining a) evaluation according to adjectives in response to partial design element change and b) function obtaining sensitivity of design element based on adjectives that conform to the design concept. Response of the database was also evaluation target, so it is loaded on the designated server (http://kansei.web.infoseek.co.jp/pts/top_12_05.html) to enable access via the Internet.

(2) Result of questionnaire for aesthetic feelings

The questionnaire for aesthetic feelings was conducted for the following three items.

- Five-scale SD evaluation by looking at pictures of Bridge K (1, 2, 3, 4, 5)
- Five-scale evaluation whether design concept is satisfied by comparing pictures of Bridge K and Fig.13 in Section 6
- Checking adjectives among 43 adjective pairs in Fig.2 that conform to the design concept in Fig.13

a) Five-scale SD evaluation

Table 6 shows the SD evaluation result regarding the adjectives selected in Table 2, although the actual questionnaire was conducted regarding the 43 adjective pairs shown in Fig.2. In Table 6, p values are shown in the parentheses, where the value smaller than 0.05 shows significance level of 5% and is different from the median 3.0 (shaded columns).

The weighting of the adjective “urban” is –1, and the smaller the value is, the better. Bridge designers and male students marked p values equal to or less than 0.05 in all the adjectives, indicating that the image of Bridge K matches the adjectives well. Fe-
male students also marked p values equal to or less than 0.05 in adjectives other than “merged into background” and “dynamic”. Therefore, it can be said that the adjectives in Table 2 converted from the design concept are appropriate.

b) Conformance to design concept
The questionnaire was conducted in accordance with five evaluation levels by showing the subjects the pictures and the design concept shown in Fig.2 and asking them whether the pictures conform to the design concept. Table 7 shows the average of the five-scale evaluation result indicating the degree of conformance to the design concept.

The average for bridge designers in accordance with five evaluation levels is 3.24, which is higher than the median 3.0. The degree of conformance for male students is 3.762 and a p value is extremely higher than the median, which is 0.0014 < 0.05. The result indicates that the design concept and the impression received by the pictures are quite matched. The average for female students is 3.045, only slightly higher than the median 3.0. Accordingly, it has been verified that the completed Bridge K conformed well to the determined design concept.

c) Adjectives conforming to design concept
Table 8 clarifies the top 10 adjectives listed in the order of the total number of people who judged each adjective as conforming to the design concept, including the adjectives determined in Table 2. The vertical columns show the number of each subject who judged each adjective as conforming to the design concept, and the column on the rightmost shows the order determined by adding the total number of people in all the three subject categories.

The adjective “merged into background” derived from the design concept was the largest in the number of people who judged it as conforming to the design concept. Similarly, the adjective “harmonious” derived from the design concept was the third largest. Regarding these two adjectives, image received from the pictures matches well with the design concept. There were only two people who judged the adjective “urban” as conforming to the design concept, meaning people have an image completely opposite to that of urban and that Bridge K reflects image of countryside well. The order of “neat” and “balanced” was not so good and there was only small number of students who judged them as conforming to the design concept. On the other hand, almost half of the bridge designers judged them as conforming to the design concept, and thus it is appropriate to say they conform to the design concept.

(3) Evaluation of database functions
The questionnaire result regarding the functions of the scene evaluation and design support system is as follows. The subject was only limited to bridge designers because this questionnaire requires a certain level of design or consensus-building work experience.

a) Evaluation by each subject is obtained according to adjectives in response to partial design element
change. More specifically, using the evaluation simulation to see how evaluation changes when girder color or substructure is changed, score of the adjective describing image can be displayed immediately by selecting the applicable category according to items.

b) Sensitivity of design element is obtained (which design element is important is clarified) according to subject by selecting multiple adjectives that conform to the selected design concept and their weightings. Evaluation was conducted for another two functions derived from function b).

Function b-1): This function displays the total category score that represents the selected multiple adjectives and their weightings. It displays design items and category score (total score) to show the image that matches multiple adjectives converted from the design concept and their weightings. The higher the score is, the better the evaluation result.

Function b-2): This function displays pictures of bridges in descending order of total score of the selected adjectives and highly and poorly ranked items within the influential category to show the image that matches multiple adjectives converted from the design concept and their weightings. Bridge with a higher total score matches better with the image described by multiple adjectives. This function also displays bridges with lower score so comparison can be made between bridges.

The questions asked for evaluating the functions a) and b) are shown in Fig.14.

The questionnaire results regarding functions a), b-1) and b-2) are shown in Table 9.

Judging from Table 9, there will be no big pattern changes among functions a), b-1) and b-2), so studies will be made by questions below.

In question no. 1, there were none who answered “not necessary” for the presented function, and not less than 70% answered “necessary”. In particular, 89% needed function b-2), and it is validated that functions a), b-1) and b-2) are necessary for design and consensus-building work.

Question no. 2 asks about usefulness of the function. The number of people who answered “useful” was smaller than that in question no. 1, which was 67% or more in percentage. There were none who answered “not necessary” as in question no. 1. Thus, usefulness of the system was also validated.

In question no. 3, the necessity of evaluation according to subjects was divisive. More than half of the people answered “necessary” but 22% to 27% answered “not necessary” thinking that detailed classification of subjects is not necessary if the primary purpose is to build a consensus. In actual cases, there are various people involved in addition to bridge designers and students, so classification to some extent seems to be necessary.

In question no. 4 asking about other functions user want, there were requests for more detailed classification of scene, visualized results, (selectable) structures other than girder bridge, less bothersome weighting input, more detailed color classification, etc. These requests will be handled in the future for further improvement of the system.

| Question 1. Does it seem that this function is necessary? | Function a) | Function b-1) | Function b-2) |
|----------------------------------------------------------|-------------|---------------|---------------|
|                                                          | necessary   | necessary     | necessary     |
|                                                          | 13          | 14            | 16            |
| Question 2. Does it seem that this function is effective at stages of the design, the evaluation, and the consensus building? | effective   | effective     | effective     |
|                                                          | 12          | 12            | 13            |
| Question 3. Does it seem that the appreciable function of each subject is necessary? | necessary   | necessary     | necessary     |
|                                                          | 9           | 10            | 10            |
| Question 4. Besides, does it seem that it only has to provide what function? | planning, comparative, basic design | planning, comparative, basic design | planning, comparative, basic design |
|                                                          | 15          | 16            | 16            |
| Question 5. Does it seem that this function is effective in which phase (multiple answers allowed)? | renewal, resident explanation | renewal, resident explanation | renewal, resident explanation |
|                                                          | 8           | 8             | 8             |
| Question 6. How about the response?                      | good        | good          | good          |
|                                                          | 12          | 11            | 11            |

Table 9 Questionnaire results regarding functions a), b-1) and b-2).
In question no. 5, many people (83%) answered that the system was most effective at planning stage, followed by explanation to residents, preliminary stage and basic design stage, and 50% to 61% answered the system was effective. The reason why percentage of detailed design stage was small is probably because there is not so much degree of freedom for design at this stage. About half of the people answered redesigning stage, but use frequency will increase more and more in the future in occasions such as partial maintenance and color change at time of repainting.

In question no. 6 asking about response on the Internet, it depends on whether the Internet is too busy or performance of client’s PC. Only one student answered “slow” and 61% or more people answered “good”, indicating that database can be used from server via the Internet without problems.

Lastly, as overall impression, a lot of people commented regarding function b-2) that it was quite easy to image the bridge while referring to pictures of similar bridges listed in ascending order.

8. CONCLUSION

In this research, scene design support system for girder bridge has been established to quickly respond to various changes at consensus-building stage. To establish this system, basic needs and output method to assist design work were studied. The following is the summary of the achievement of this research.

(1) Functions necessary for the scene design support system for girder bridge have been summarized to quickly respond to various changes. Then, concept of the Kansei database and how to use the database in practical scene design work have been summarized.

(2) In order to assist scene design, proposals have been made on evaluation simulation according to category change and display method for bridge examples that conform to design concept and items that largely affect evaluation.

(3) The scene design support system that can operate via browser has been established. This system is helpful when conducting various evaluation simulations, quickly creating scene design plans, and creating design plans.

(4) Through application of this scene design support system to the actual bridge scene design case, it was confirmed that category scores calculated from adjectives describing image that are converted from the selected design concept and their weightings were appropriate. It was also confirmed that evaluation in response to design element change was also possible.

(5) The questionnaire survey regarding Kansei evaluation using the scene design support system and database functions were conducted to bridge designers and students who were actually engaged in planning, designing and consensus-building operations. While showing them pictures and design concept, appropriateness of evaluation using adjectives converted from the design concept and conformance degree to the design concept were confirmed. Further, necessity, usefulness, and response have been confirmed.

In recent years, there have been rising demands for public involvement (PI) in infrastructure involvement, but the issue lies in how and how much opinions of residents without expertise are considered. It was validated through the achievement of this research that the Kansei evaluation technique proposed in this research was one helpful means for PI promotion, and it is expected that the achievement may suggest what future infrastructure development should be like. The achievement can be fully applied to other types of bridge such as arch bridge and cable stayed bridge, as well as other civil structures like dams, port facilities and river structures.

When the Kansei database is realized which reflects aesthetic feelings of various subjects toward structures requiring multiple construction works, consensus building with public involvement, which has never been possible before, is enabled. The Kansei database is expected to be used as the database to assist effective use of future required assets (asset management) at particularly long maintenance and control stage within a life cycle.

Finally, remaining issues for more practical use of the scene design support system are described as follows.

(1) Residents’ needs and sense of value change

...
during a long service period of maintenance and control stage. Studies must be conducted on how to accumulate and reflect them into the Kansei database to promote effective use of facilities. The questionnaire method and countermeasures for improving value of facilities need to be considered too.

(2) Questionnaire survey needs to be conducted to ordering companies, designers or various other subjects to create the system reflecting various aesthetic feelings.

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