A STUDY ON THE ROAD DESIGN INFORMATION SYSTEM BY A PATTERN LANGUAGE METHOD

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Abstract

An approach to build an intelligent database system through managing information techniques, including not only existing approaches to database collection, but also knowledge-based systems, expert systems, hypermedia, on-line information retrieval, etc., was applied to construct a problem-solving support system for road space design. The system is considered to be useful for:
(a) specification of the context of the ground the design was placed, (b) clarification of subject issues, targets, effects, etc., of the design, (c) identification of problem structures concerning composition and spatial arrangement of physical elements based on the database system in the design.

1. Introduction

In recent years, a growing demand has arisen to create comfortable spaces and beautiful landscapes, and establish a harmonious relationship between environmental conservation and the natural environment, leading to an increased need for "design" in civil engineering works. Just as remarkable technical innovations have been made in the field of computers and network communications, the computer has also ceased to be a simple tool to calculate figures in civil engineering, and the use of the Internet to collect and transmit information, design-assisting systems such as CAD, and CG systems to visualize information have become widespread.

With this in mind, the authors have undertaken research with the objective of developing a road-design-assisting system that will help create better designs by providing support in such areas as image-configuring and problem solving in road spaces and landscape design *(Sakakibara et al., 1993, 1995a, 1995b, 1996a, 1996b)*. In developing such a system, one of the most important problems concerns the "selection" of design information that will likely have a great effect on improving the performance of design-assisting systems.

Our research, based on the model of C. Alexander's pattern language *(Alexander, 1977, 1979)*, involved the creation of a database by selecting and organizing specific "problems" related to every aspect of road design and "solutions" to these problems from the relevant literature, and placing this information in a network-type data structure linked to related design information.

In light of the recent popularity of the Internet, construction of the system was achieved by creating a database on a WWW (World Wide Web) server, and attempting to create a three-level system that can be used without depending on a machine or OS (operating system).

2. Fundamental Methodology of Road Design

2.1. Road Design Information

The road-design-assisting system conceived of by the authors is a system based on the means and methods of solutions to problems in landscape and space design that searches for and finds their effects. Its ultimate objective is to create good design, not to computerize the creation of design. The structural elements of the final design or the proposed conditions are made to act as a base for designers to work from, and the system's construction is designed to search for and find means and methods.

In the past, the following three categories of data were handled and thought to be vital to road-design assistance as design information:

(1) Selecting examples of past road improvements from the literature and organizing them into categories such as improvement outline, improvement content, and special characteristics of the landscape *(Sakakibara et al., 1993, 1996a)*.
(2) Selecting design information necessary for landscape and space creation from road attributes, material elements, material methods, and landscape characteristics of 1. that are related to the effectiveness of the improvements made *(Sakakibara et al., 1995a)*.
(3) Ordering into levels the fundamental processes to decide at a comparatively early stage (including the organization and planning stages) in the design of the road structure. This also involves information related to the landscape, material elements, material methods, and improvement effectiveness *(Sakakibara et al., 1995b, 1996b)*.

With the exception of 1., this information is structured in a reciprocal relationship of three categories (material elements, material methods, improvement effects). Therefore, when the design problem is determined, it becomes possible to look for information that will act as a solution.

2.2. Qualitative Improvements in Road Design Information

The road design information in our research carries with it the presumption that the information will be used to find "solutions" to the "problems" in road design structure and elements of road spatial structure. However, to be used, the kind of information that was mentioned in 2.1 requires that the user (designer) discover the "problem" oneself, and after identifying it, find a "solution." This also includes consideration of the mechanism and the circumstances (relation to a variety of surrounding elements) that caused the problem. In this situation, the user's burden is heavy, and as design aiding information, it can not always be said to be of the highest quality. Thus, a higher quality of information is desired.

To improve the quality of design information, a desirable solution should be prepared to deal with the problem. This would involve selecting information with a data structure that can be expressed and transmitted according to a concept based on the information and meaning that is linked to the whole as a type of support information. In addition, after determining the problem that results from a specific set of circumstances, by preparing the desired solution to the problem, the quality of the design information can be improved.

In this paper, we will discuss Alexander's pattern language as a method for solving the above problems, the means of its application in 3., and finally, in 4. the structure of a system to deal with design information on the Internet.

3. Road Design Information Expressions Using Pattern Language

3.1. Pattern Language (Alexander, 1977, 1979)

The word "pattern" refers to rules that are created to express the relationship between a set of circumstances and the solution to that problem. Each pattern exists independently. The selection of a pattern involves the standardization of selection standards by following a set form, and establishing links between that pattern and related pattern information and a reciprocal relationship between the patterns. Then by treating the assembled patterns as a language, a large number of combinations can be generated.

A sequence is given to the patterns, and extends from large patterns such as ground form and natural environment to small patterns such as road shape, overall road construction, road construction materials, and greenery. In addition, because each pattern is linked to a "bigger" pattern at a specific higher level in the language and at a lower level or "smaller" pattern, they are set in a higher level pattern, surrounded by patterns of the same level, and combined with patterns of a lower level. However, because it is difficult to precisely capture the essential information that will remain unaltered in the future, a pattern can be thought of as something to repeatedly renew many other patterns.

3.2. The Role of Pattern Language

Two specific examples of Alexander's pattern language that have been applied are "The University of Oregon Master Plan *(Alexander, 1975)* ", and "The Construction of Eishin Gakuen Higashino High School *(Matsuba, 1985)* ". These included the creation of a pattern language by directly requesting and collecting the opinions of people, the future users of the facilities, concerning the use of space and architectural design of the buildings on the site.

Compared to architectural projects, civil engineering works (with their road improvement projects, project time frames, problems with public systems, intended use of the structure, the length of time users spend there, and the surveying of future users' opinions) involves many people, and therefore, is no simple undertaking. However, the following concepts can be used to collect the opinions of a large number of users and make use of them:

(1) Through the use of multimedia equipment, the 21st Century Road Committee, the basic policy-making arm of the Road Deliberation Council is proposing the idea of making use of user opinions and proposals through a policy of public involvement to the Ministry of Construction. This policy was designed to ensure that time was set aside to collect a wide range of opinions and views (between May 1 and July 31, 1996, a total of 35,674 people responded with a total of 113,316 opinions) as well as informing people of the decision-making process of a particular plan. In the future, the council will propose ideas for road planning and construction to the Ministry of Construction.

(2) In the Ministry of Construction's "Streets of Life Construction Project," roads were made with the participation of local residents concerning road space improvement, and as part of measures taken to improve new roads at a governmental level, citizen's opinions were collected.

From the results of this experiment, it appears that collecting road-design information (patterns) is necessary, but a pattern language method would be a highly effective alternative in this situation.

Civil engineering road improvement projects, unlike architectural projects that use surface space, use linear space. The following are some ideas concerning the applications of pattern language.

Road design that occurs after determining the elements of linear road form and the width of the area involved is a matter of matching a set road surface plan within a certain environment through material elements, including the surrounding area and the handling of space. However, it is necessary to index a "special solution" (pattern language) that fits the particular conditions of the place (in general this consists of a number of individual places) where the design is being carried out. Because pattern language is a collection of patterns that are particular solutions to specific conditions and problems concerning design elements, by creating a database of patterns (these patterns are called "general pattern solutions") beforehand that correspond to a variety of conditions, it becomes possible for the designer to [skillfully, easily, conveniently] make a structure from a combination of solutions that correspond to the situation. At this point, a general solution can be selected from the literature relating to actual road improvements in mountain regions in the same way as the design information that has been collected thus far. Moreover, as we will discuss below, because the method of pattern selection is performed according to a set of procedures that a designer creates; it is also possible to add data as needed and include a "special solution" by making a pattern according to the "intention" or "concept" of the design.

With a special solution, the suitability of the solution can be a problem in itself, making it a necessary precondition for this solution (known as a "satisfactory solution") to be suitable as a pattern language in terms of syntax and context. Analyzing and evaluating whether or not a special solution is a satisfactory solution can be left up to the designers, and the planners and advisers they are working with. In cases in which the satisfactory solution is the sole solution, this can be called the most suitable solution (by definition). In cases in which there are a number of alternative plans, evaluation can be carried out using some form of standard or method and the most appropriate solution can be selected.

The special characteristics of the road design information discussed in 2. and the information that has been created in this process are indicated in Table 1. "Data structure" and "intelligence expression" are different, but regarding the "specific design problem," it is only possible to accept the "pattern language method" as data. In addition, in the "links between elements" category, it can be seen that "pattern language" contains links between elements in the overall design. It is then possible to create the following process as a road design that accentuates the special characteristics of this design information:

(1) Index the problems and solutions in a landscape structure or space structure using a pattern language as a particular special solution that is suitable to a site as the object to improved.
(2) Determine road structure from the fundamental process data to decide road structure, and determine as well the structural elements related to the structure.
(3) Reference a large number of actual examples to increase the quality of detailed concrete design through the improvement example data of each structural element of the road.

The pattern language method applied in our research is a method of space design used in architecture. Because in the past research methods for space design in civil engineering have almost never been used except in research by the authors and various manuals, it is necessary to attempt to arrange something appropriate to civil engineering space design by incorporating a method from another field. In addition, compared to the element-classification-type manuals of the past, the design information that was collected using this method has the following characteristics and advantages:

(1) The "problems" related to design in space structure and landscape structure can be determined.
(2) A "solution" to a problem can be found.
(3) The pattern contains an overall link and a sequence.
(4) Data structure can be applied to hypertext for use in computers.
(5) By using a computer, a new type of design assisting system can be created.
(6) Productivity in road design can be improved.

type of information / subject of comparison	road construction elements	basic process to decide road construction	pattern language method
data structure	parallel structure	layered structure	network-type structure
intelligence expression	production rule-type	frame-type	hypertext-type
specific design problem	designer-generated	designer-generated	possibilities of registered elements
links between elements	none	vertical relationship between identical road construction	all related elements

Table 1: Comparison of road design information

3.3. Generating Patterns Based on Road Improvement Examples

Patterns can be divided into three types of sequences as indicated below. Pattern selection can be performed based primarily on the "problems," "solutions," "links to other patterns" in landscape forms at each of the levels. At present, 112 patterns have been selected:

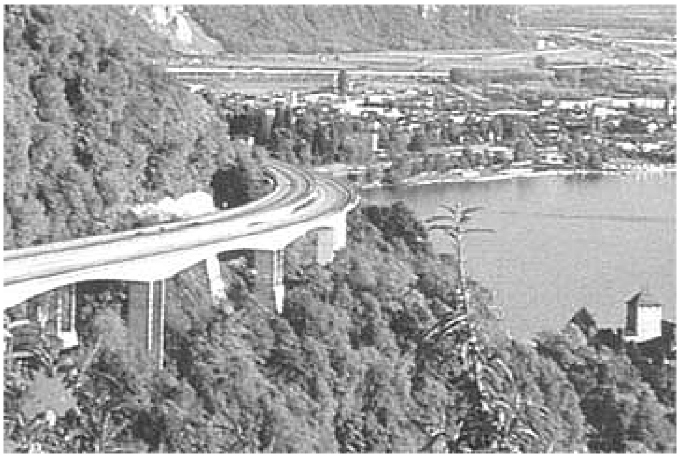
(1) Regional characteristics: topography, plant life, land use, landscape resources, etc.
(2) Road characteristics: vertical and horizontal shape, road construction, greenery, etc.
(3) Finishing touches: slope protection, retaining walls, shrubbery, pavement, etc.

Photograph 1 and Table 2 are examples of patterns generated based on the pattern form discussed in 2.1.

On the left side of Table 2, the form of the pattern is indicated, and on the right side, the content of the selected pattern is explained. The area that is printed in gothic letters in the c) section indicates a link to a pattern of a higher level, while the gothic print in the g) section indicates a link to a pattern of a lower level. By converting this link information into HTML (HyperText Mark-up Language), discussed below, organic links can be formed between the patterns, an overall coherence can be given to the design information, and the database structure can be constructed in a network-type format.

Generating patterns is a design information selection task performed basically with text, and differences in expressive content arise according to the creator's abilities, sense, and experience. To generate patterns, it is necessary to create information in an environment that increases the accuracy of design information with a system that can check questionable information with a number of people and evaluate it.

Among the problems and solutions selected as patterns are those that are local specific and exist in no other site and that are site specific; those that are time specific and that change function and structure along with the era; and those that are either universal or unchangeable patterns and those that aren't. Therefore, it is difficult to generate a pattern that can be used in all types of road improvement



Photograph 1: Road improvement example

pattern form	Selected pattern
a) Pattern name	elevated mountain highway
b) Photograph showing basic form of pattern	photograph 1
c) How the above relates to the pattern before and after, and how it effects the outcome of the larger pattern	Greenery is a vital natural resource that can be useful in protecting environmental destruction in mountain areas.
d) Main pattern 1. Heading in bold letters for a short compacted sentence explaining the gist of the problem 2. Text (experiential background of pattern, proof of the pattern's effectiveness, variety of appearances in the pattern environment) that explains the problem	**By overlooking the protection of slopes where greenery grows, and lowering or raising the level of the ground, the problem of environmental destruction continues**. If the ground is lowered or raised to an extent that is unnoticeable from the exterior landscape, no sizable problem is likely to occur, but destruction of the natural environment increases with a greater lowering or raising, and it is necessary to spend a long period of time getting used to the surrounding plant life. To realize a harmonic relationship with the natural environment, more than paying attention to the revitalization of the environment after destruction, it is possible to maintain the area by building instead elevated roads, bridges, or plank bridges in places where lowering or raising the ground are not appropriate.
e) Solution that shows the key points of the pattern. The physical and social aspects as well as range that are needed for the solution to a set problem. Clear statement of what should be done to realize the pattern.	On roads that pass over steep mountain slopes, an elevated road can be integrated with the mountain slope to keep environmental destruction to a minimum. To create harmony between the exterior landscape and the area, the piers of elevated roads should be designed to be as slender as possible to maintain the overall landscape.
f) Short slogan that indicates main parts of solution and diagram of the solution.	Elevated road construction
g) Showing the completion of the pattern itself, and with the end of the latter, link to all of the small patterns to complete the system.	Every effort should be made to ensure that the equipment that is attached to the road not stand out, and to execute a design that is unified with the structure. In addition, to minimize the volume of the structure as it appears in the surrounding landscape, a beveled construction method is advisable for bridge piers.

Table 2: Examples of pattern selection

projects. There is a necessity, it is thought, to generate a pattern language from different types of road design information including road classification and geographical conditions.

4. Construction of a Road Design Information Database

4.1. Computer Environment

Recent personal computers have shown remarkable advances in performance and operation environments as well as being equipped with network use environments as standard functions. In addition, due to the spread of the Internet, it has become possible to exchange data regardless of the OS. By simply using Netscape Navigator or Internet Explorer WWW browsers, it is possible for anyone to access information on a HTML-created Web page in the same way regardless of the type of machine or OS. It is of course an educational system, and because it has become relatively simple for workers in small-scale businesses and individuals to connect to the Internet, it is becoming convenient to transmit and search for information.

In this type of computer environment, client/server (C/S) system development has become possible, and through the centralized management of data, the same data can be shared with other users. In addition, simply by using a WWW browser, a user can make use of all of the functions in a system, so the only thing a user really has to do is to update the WWW browser.

Assuming that the user environment is as above, the following merits can be given for developing an open system on a network:

(1) Using the system is extremely easy.
(2) It can be used for an unlimited amount of time, from an unlimited number of places, and by anyone.
(3) Updating the data can be done in real time.
(4) Anyone from outside the system can easily add something to the database, and an increase in the amount of information can be expected.
(5) Places for a number of people to share information can be offered.
(6) If equipped with a function to allow conversations between users who are simultaneously connected to the system, it is possible to link to a cooperative project in a virtual space.

It is also possible to imagine the following demerits:

(1) If due to a power failure or some other problem, a WWW server goes down, the system would be unusable.
(2) If something goes wrong with the network, the system would be unusable.
(3) It is possible that data might be destroyed by some people.

As can be seen, the merits of constructing a system on a Web server in a network environment are many. The demerits could also be dealt

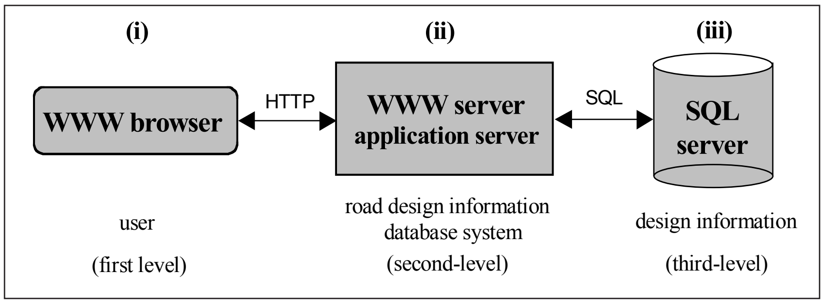


Fig. 1: Three-leveled system

with by using a reliable server and strengthening security.

4.2. Objectives of System Construction

Because applications and data had to be transferred by some kind of electronic information media (for example, CD-ROM or FD), stand-alone systems of the past were extremely inefficient in terms of system integration and the labor involved. In addition, the user also had to perform the troublesome task of installing the electronic media in a system that matched the user environment.

Regarding the computer user environment discussed in 4.1, if a three-level system was constructed as indicated in Figure 1, the merits listed above would become apparent. In other words, the users (designers) in (i) in Figure 1 would be able to use the system simply by accessing the WWW server in (ii) from their own WWW browser. Updating the system and data using a form such as the C/S form could be done simply by performing (ii) and (iii), and the updated information would be communicated back to the (i) user in real time.

4.3. System Construction Environments

In constructing such a system, the (ii) WWW server system in Figure 1 and the (iii) SQL (Structured Query Language) server

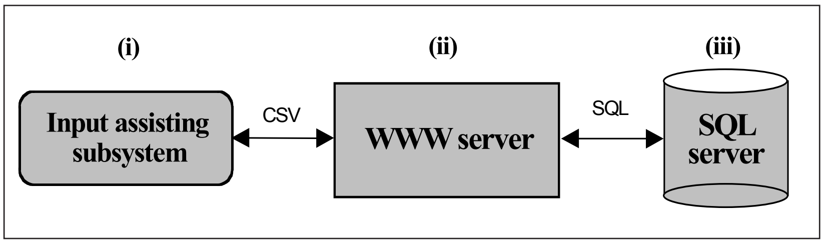


Figure 2: Flow of data

system would be necessary. In our research the majority of the software used in the prototype environment we constructed, such as the Linux (unix) OS, was available as freeware.

For the WWW server, we used Apache (WWW server software), which includes PHP/FI (the Personal Home Page Construction Kit/Form Interpreter), making it possible to access a SQL server.

The SQL server used was a kind of RDBMS (Relational Database Management System) developed by David J. Hughes called mSQL. Because it was possible to access it from K-Prolog, manufactured by the ISAC, Inc., it was possible to begin database searches with reasoning.

In addition, as a device to perform data input, we used a Windows-based personal computer connected to the network.

5. Developing an Information Search System for Road Design Assisting

5.1. Recording Design Information

The selected design information (patterns) was inputted as data and registered in the database as indicated in Figure 2. Because the patterns consisted of two types of different information, text data and image data, an accurate and efficient means of information input was desired. To achieve this, the authors created a subsystem on a computer with *Access* of Microsoft to assist the input process. Even at this level, it was possible to search for information and other operations, such as data checks, also went smoothly. An example of data input using the input assisting subsystem can be seen in Figure 3.

This example primarily involved the input of text. The size and brightness of the images, which were inputted with a scanner, was adjusted using Adobe's *Photoshop*, and were pasted to the right side of the page as seen in Figure 3 as well as being saved in a file. The data constructed in this way was converted to CSV form (a form of separation using commas to separate rows of text by category), and transferred the file to a WWW server. In order to register information in the database, a registration (activated by clicking the save icon) was chosen on the Web page, and a SQL command was put into effect enabling the data to be registered on a SQL server. Because images cannot be processed at the same time, it was necessary to transfer a file by another means such as ftp.

Figure 3: Pattern information input example

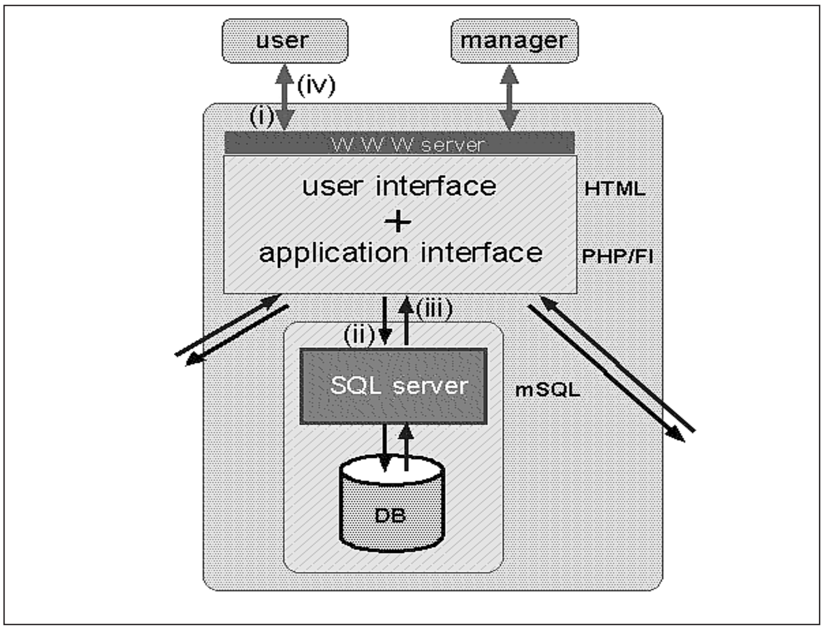


Figure 4: Flow of information in system

5.2. Developing a Design Information Search System

To realize the functions discussed in 4. in a design information search system, several programs were arranged in the WWW server as seen in Figure 4. The HTML document includes the program controlled by FHP/FI script. A detailed explanation of the process can be seen with the numbers in Figure 4. In other words, based on the keyword information input on the Web page (i), a search request is made to the SQL server after a query is made (ii), search results are produced on the spot in HTML script (iii), and this information is displayed for the user (iv). In addition, the manager (developer) can continue to develop programs on the WWW server using telnet or another system.

On the server, information flows as indicated by the arrows in the figure. An information-search that accesses an SQL server operated by another server engine in represented by the arrows that point diagonally outside the flow chart. Separating the WWW server and the

Figure 5: Example 1 of pattern information search

Figure 6: Example 2 of pattern information search

SQL server and dispensing the operation contributes to an increase in the speed of the system.

5.3. Using a Design Information Search System

Accessing the system from a Web browser is one condition in the system we have developed in our research. After connecting, the screen shown in Figure 5 appears, and the user is prompted to input a keyword. In this example, the keyword “environmental destruction” has been input. If no keyword is entered, all of the stored patterns will be displayed.

Next, by clicking the “search” button located below the keyword input box, a display of the pattern name, as seen in Figure 6, that includes the words “environmental destruction” in the document will be displayed. In this example, seven kinds of patterns are registered.

Next, after getting some hint from the pattern name, if one clicks on the “search” button located to the right of the pattern name, a search by the SQL server using a query begins. The content of the pattern as seen in Figure 7 is then displayed as the result of the search.

By focusing on bridge piers, the keyword (pattern name) “beveled construction” is chosen. Then by clicking on the “search” button, the content of the pattern as seen in Figure 8 appears.

As this example illustrates, first, the user indexes the pattern with a keyword related to the problem or solution they are searching for. And by repeating the process of accessing the related pattern from the information given for related patterns within the initial pattern, a pattern language with a particular special solution that fits a certain site

Figure 7: Example 1 of pattern content display

(i.e., a series of patterns) can be found. In addition, the new design problems and solutions that are found in the process can be linked to the creation of new design through the accumulation of knowledge, and this new pattern will also be included as part of the language.

6. Conclusion

In this paper, we have first considered some of the problems involved in adapting pattern language that originated in architecture to civil engineering design, and discussed methods of making it function in road design. Next, we have discussed patterns as design source information, a database system for road-design assisting through a special design solution or pattern language, and a method of con-

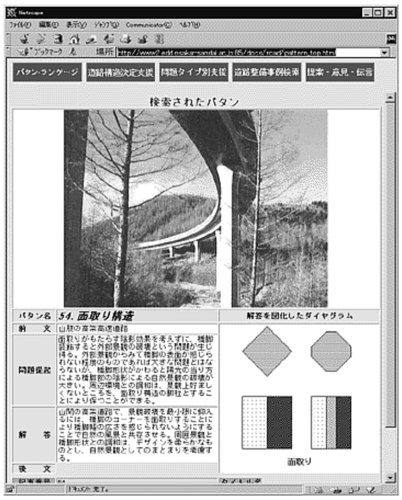


Figure 8: Example 2 of pattern content display

structing this on a WWW server. In addition, the database that was actually constructed using a three-level system could be thought of as a heuristic database unlike databases of the past such as search-oriented-type databases and expert systems. We have shown the uses and possibilities inherent in a different kind of database.

We have also shown that pattern languages, even when used in civil engineering rather than architecture, have the possibility to create effective design methods in a design process such as design improvement.

In the future, we hope to develop intelligent database systems *(Parsaye et al., 1989)* by applying reasoning functions and object-oriented, while at the same time making advances in pattern selection and increasing the accuracy of the information.

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