SUSTAINABLE DESIGN AUTOMATION AND MANAGEMENT USING XML

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ABSTRACT : Concrete slab bridge is one of most common structures employed for local road constructions because of its simplicity in design and construction. Computer applications were developed to automate the repetitive computation for these simple structures. However, in most cases, managing the electronic documents produced by these applications has not been incorporated with design automation application yet. Resultant documents are often managed by individuals and disappear as time goes by due to lack of systemic management. This paper introduces a Web-based application developed to not only speed up the design process but also enhance the collection and manipulation of resultant electronic documents.

Key words: Web, Concrete Slab Bridge, Design Automation

1. INTRODUCTION

Two-span concrete slab bridge is one of the structures repetitively employed for local road constructions because of its simplicity in design and construction. Every year, a significant amount of simple concrete slab bridges are designed and constructed in Korea. In most cases, the configuration of two-span concrete slab bridges is about the same regardless of their size and topographical features, which in turn makes the design process relatively simple compared to other structures and somewhat repetitive. Design of such simple and repetitive structures as two-span concrete slab bridge is often considered as easy but time-consuming task and therefore assigned to entry-level engineers, which sometimes ends up sacrificing productivity in the design process and reliability of structural stability.

Professionals have attempted to expedite the repetitive design process and secure structural stability by utilizing computer applications that automate repetitive calculations and produce relative documents, which has demonstrated time savings in the course of designing simple structures. However, most of design automation applications have been developed to use in a stand alone computer. The practice of manipulating electronic documents containing the result of calculations has remained the same. Once the electronic documents generated by these applications are tailored and printed for authority's approval, they were most likely managed by those who designed the structure and sometimes disappear in few years as responsible individual relocates. This is one of many reasons why we sometimes can not locate design documents of a certain structure that needs to be repaired and maintained.

The Internet technology has a potential to better manage those electronic documents produced by design automation applications for a longer duration. If electronic documents are collected in a central repository and retrieved over the Internet whenever needed, document omission and redundant duplication could be dramatically reduced. We may even be able to organize the lessons learned from the previous projects and utilize them to enhance the next project. Web-based project management, which manipulates information in the central repository, has already been utilized to some extent for many Architecture, Engineering, and Construction (AEC) firms to build a project legacy database consisting of engineering reports and CAD drawings and hand it over to succeeding projects. The authorities supervising the construction industry, such as the Ministry of Construction and Transportation in Korea, may also be interested in utilizing the project legacy data to better make decisions for repairing and maintaining the built structures.

However, current design automation applications are not incorporated with Web-based project management. They are basically designed only to expedite the repetitive design process and little consideration was given to manipulating resultant documents. Those who design two-span concrete slab bridges using design automation applications, for example, still need to take additional steps to get the design documents transported to a central repository. Unless a certain system that enforces engineers to send documents they produce to the central repository immediately, they tend to put it off until some other day when they don't get pressed by heavy workload. Some engineers may eventually forget to their engineering documents sent to the central repository and move on to a next project. It is reasonable therefore to speculate that sustainable design document management in the cyberspace would not be easily accomplished unless the entire process from the engineering design to the document management is incorporated in one system.

2. DESIGN AUTOMATION

A variety of design automation systems have been developed and utilized for facilitating the simple and repetitive design. These applications usually take dimensions of a structure to be designed, loading conditions, and soil conditions of the site and perform a routine computation to check the structural stability with a given structural configuration and generate engineering drawings. Professionals in Korea have been very active in developing those design automation applications. Hangil IT (http://www.aroad.co.kr) is probably one of the most active software venders in Korea that have been developing and providing a series of computer applications for facilitating the design of such repetitive structures as box culvers, retaining walls, and simple bridges. It provides, for examples, ARcBridge that is developed to facilitate concrete bridge design. It helps engineers design various types of concrete bridges including portal type Rahmen bridge and slab bridge.

Although these computer applications have demonstrated a significant amount of time savings in the process of designing simple and repetitive structures, they seldom support resultant document management. Engineering firms often depend on a separate document management system for building project legacy data and use them for succeeding projects. They even prepare a protocol to better collect and circulate the resultant engineering documents. However, the omission and duplication of information still seems to be hardly avoidable.

3. EMERGING INTERNET TECHNOLOGY

Recently, new Internet Technologies such as Extensible Markup Language (XML) and Scaleable Vector Graphics (SVG) have been introduced to the construction industry. XML is a text format designed to manipulate large-scale electronic publishing and data exchange over the Internet. SVG is an application of XML, which defines tags for illustrating vector graphics on the Web page. Combination of these technologies provides a foundation for developing a Web-based parametric design support system that may facilitate not only the design process of simple structures but also the manipulation of the resultant engineering documents.

3.1 Extensible Markup Language (XML)

XML is a simple and flexible text format derived from the ISO 8879 Standard Generalized Markup Language (SGML). It is called extensible because it is not a fixed format like Hyper Text Markup Language (HTML). Originally designed to meet the challenges of large-scale electronic publishing, XML is also playing an important role in the exchange of a wide variety of data on the Web. Since XML defines the structured information in a software-neutral text file, it can be recognized by virtually any computer systems. Thus, XML can be used for building project legacy data that don't depend on a specific computer system, which is important because no one knows what kind of computer system would be dominantly used in 30 years form now on.

Freedom in defining whatever we like to describe using XML, however, could generate too many diverse descriptions of the same object, which would make it difficult to share one's information with others. Tserng and Lin [1] pointed out, after they built an electronic data acquisition model for project scheduling using XML, that the variety of data structures project participants used had hinder them from gaining efficient access to information of multi-contract projects. Zhua and Issab [2] indicated that a well developed XML schema of the classified construction information is one of the critical key issues for successful data exchange. Professionals in the construction industry quickly realized the necessity of establishing a standard to describe engineering documents in XML. In 1999, International Alliance for Interoperability (IAI) proposed aecXML, which is an XML-based language designed for exchanging information in the AEC industry. Harrod [3] noted that "the main idea with aecXML is to not only establish some standard ways of structuring building data but also to do it so as to enable automated processing of that data as much as practicable".

3.2 Scalable Vector Graphics (SVG)

SVG is an application of XML, designed for describing two-dimensional graphics in the Web page. SVG graphics are scalable, so the same SVG graphic object can be placed at different sizes on the Web page without sacrificing graphic resolution.

For last few years, various attempts have been made to best utilize the new way of representing vector graphics. Baravalle et al. [4] demonstrated the use of SVG for producing a pictogram representation of numerical data obtained from scientific computer programs. Gonzalez and Dalal [5] presented a web service that allows end-users to specify a database query and visualize the extracted data as charts or graphs using SVG. Tautenhahn [6] introduced a 3D SVG library, which enables the Web page developers to display 3D vector graphics using SVG. The 3D SVG library is essentially a collection of JavaScript codes that create a perspective view of the 3D model using 2D SVG.

4. PROTOTYPE DEVELOPMENT

Our group decided to develop a Web application that would automate the process of designing two-span concrete slab bridges using XML and SVG in order to figure out the potential and limit of these technologies in manipulating electronic documents especially over the Internet.

We first reviewed the current process of designing two-span concrete slab bridges and listed the functions that should be provided in the Web application. Functions that would be needed are: 1) the collection of design parameters, 2) analysis of the structural stability, 3) selection of the optimum structural members, 4) generation of the engineering reports and CAD drawings, 5) representation of the vector drawings on the Web page, 6) generation and representation of the bill of materials, and 7) construction and management of project legacy data.

Design parameters collected via the Web page as shown in Figure 1 are saved in the database.

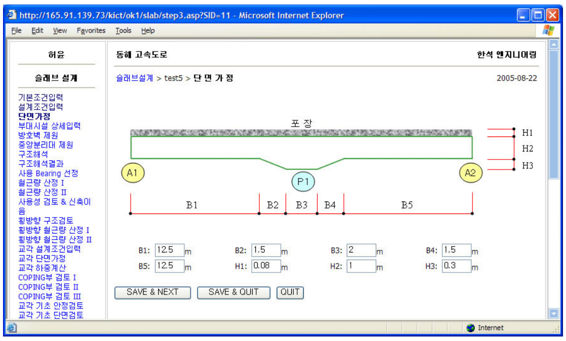

Figure 1. Web page for collecting design parameters

These parameters are retrieved by a server application and tailored into a specific format for structural analysis. For analyzing the structural stability, we decided to plug a commercial package into our Web application. This decision was made in order to take advantage of the reliability of the commercial structure analysis package and to avoid a redundant development. After the structure analysis is finished, the sever application reads the resultant file and extracts the maximum bending moment and maximum shear force. The bending moment diagram (BMD) and shear fore diagram (SFD) are generated in SVG and displayed on the Web page as shown in Figure 2.

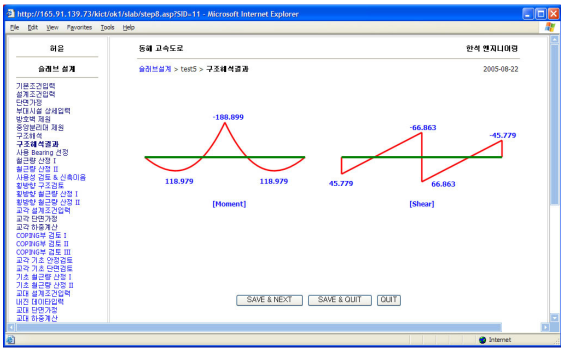

Figure 2. BMD and SFD generated by Web application

After the user provide additional design parameters in succeeding pages, the sever application selects the amount of reinforcing steel bars to secure structural stability. The resultant design information is then saved in the database for the succeeding processes.

A drawing is composed of several components such as floor plans, sections, and details. In order to allow the users to modify the scale and location of these components in the drawing, we designed an XML data island that defines the lines and texts of each drawing component as shown in Figure 3.

```
  <line>
  <s>blue</s>
  <sw>3</sw>
  <x1>123</x1><y1>15</y1>
  <x2>650</x2><y2>0</y2>
  </line>

  {Repeat as many as the number of lines
that compose the drawing component…}

  <line>
  <s>blue</s>
  <sw>3</sw>
  <x1>650</x1><y1>0</y1>
  <x2>240</x2><y2>150</y2>
  </line>
```

Figure 3. Definition of a line in the XML data island

The drawing component defined in the XML data island is stored in the database with associated project information. The scale and relative location information of the drawing component is stored separately in the database. The full drawing is created with a collection of the XML data islands by a server application as shown in Figure 4.

```
  <?xml version='1.0' encoding='ISO-8859-1'?>
  <drawing>

  {The collection of XML data island to be
included…}

  </drawing>
```

Figure 4. XML structure of the full drawing

The full drawing illustrated in XML is then transformed into a SVG document according to the XSLT configuration as shown in Figure 5.

```
<?xml version="1.0" encoding="utf-8" ?>
<svg width="15in" height="15in"
 xmlns=http://www.w3.org/2000/svg
 xmlns:xlink="http://www.w3.org/1999/xlink">
<g style="stroke: blue;
 fill: none;
 stroke-width: 3"transform="translate(0 0)
 translate(0 460)
 scale(1)
 translate(0 -460)">
<a xlink:href="step6_input.asp?doID=317">
<line x1="0" y1="460" x2="800" y2="460" />
</a>
</g>
</svg>
```

Figure 5. Sample SVG tag

Web application we developed worked successfully in the pilot test. A graduate was recruited for the pilot test and he was able to design a 12 meter long two-span concrete slab bridge within 30 minutes using our application. Figure 6 shows one of the drawings generated and displayed on the Web browser.

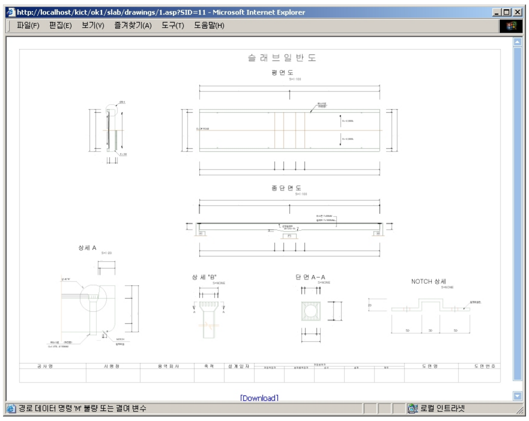

Figure 6. BMD and SFD generated by Web application

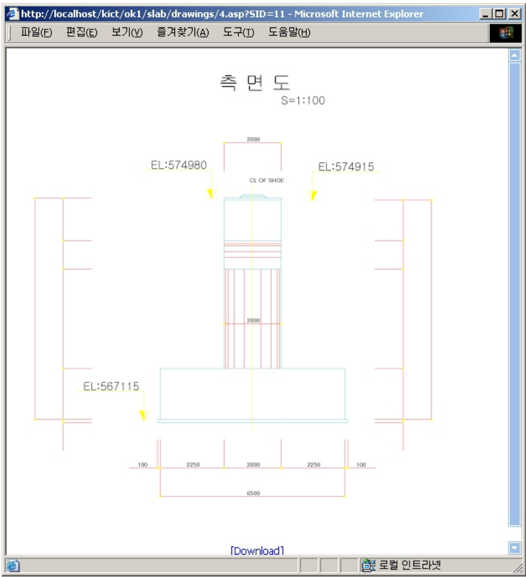

Figure 7. BMD and SFD generated by Web application

Although we did not ask that student to design a similar structure without using our application, we speculated that it would take at least entire day for him to produce the same amount of progress.

6. CONCLUSION

We believe that the Web application presented in this paper would not only facilitate the repetitive design process of simple structures but also has potential to enhance the process of manipulating the resultant engineering documents. As demonstrated in the pilot test, the entire process of analyzing structural stability, calculating the amount of reinforcing steel, and generating engineering drawings took less than 30 minutes. The time required to complete the entire design may vary according to individual superiority, but we believe that it would take way less than what should be needed with the manual process. The real benefit we are looking for is not coming from saving time in the design process. It would be rather coming from the process of collecting resultant documents in a central repository and retrieve them whenever they are needed. Our application fully automated the process of collecting the engineering document in the central repository. Engineering drawings are generated in XML and stored in the central repository. They are retrieved from the storage by user's request, converted into SVG, and displayed on the Web browser. As long as the web server maintains, all engineering documents as well as associate design parameters are kept in the server and retrieved by user's request.

We believe that the Web application presented also has potential to help small engineering companies design simple structures without investing in expensive structural analysis packages. If those Web applications are maintained by local authorities and provided to the public on subscription basis, small engineering companies should be able to accomplish their design task fast and cost effectively and local authorities should be able to collect all resultant documents automatically in the central repository and utilize them later on for infrastructure management.

In conclusion, we believe that automating the structural design process and manipulating its resultant documents on the Web environment has a huge potential to shift the process of designing simple and repetitive structures into a whole new paradigm.

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