Expert System for
Drilled-Shaft Construction Inspection

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16. Abstract Construction inspection is one of the key tasks performed by the Construction Bureau staff of the Alabama Department of Transportation to verify that construction conforms to the project specifications established by the Department. Inspectors must provide proactive inspection to avoid nonconformance issues. The inspection of drilled shaft construction is both challenging and critical since an improperly performing drilled shaft can cause significant damage to the superstructure and become a serious hazard to driving motorists. The focus of this project was the development of a computer-based tool, a resource system, to provide significant resource material on drilled shaft construction inspection. The resource system includes text, visuals and electronic versions of the forms used to document construction. The system can be easily installed on a laptop and accessed on the web, and will be available on a CD/DVD disk. The project provided an important technology transfer tool for construction inspectors in city, county and state agencies charged with the responsibility of verifying that the construction of drilled shafts is in conformity with the specifications established by their respective agencies.			
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Executive Summary

Construction inspection is one of the key tasks performed by the Construction Bureau staff of the Alabama Department of Transportation to verify that construction conforms to the project specifications established by the Department. Inspectors must provide proactive inspection to avoid nonconformance issues. The inspection of drilled shaft construction is both challenging and critical since a drilled shaft that is installed improperly can cause serious damage to the superstructure and become a serious hazard to driving motorists.

The focus of this project was the development of a computer-based tool, a resource system that can provide significant resource material on drilled shaft construction inspection. The resource system includes text, visuals and electronic versions of the forms used to document construction. The system can be easily installed on a laptop and accessed on the web, and will be available on a CD/DVD disk. The project provided an important technology transfer tool for construction inspectors in city, county and state agencies charged with the responsibility of verifying that the construction of drilled shafts is in conformity with the specifications established by their respective agencies.

1.0 Introduction

1.1 Objective

The objective of this project is to develop a computer-based tool, a resource system that can significantly facilitate the inspection of drilled shaft construction by providing inspectors the training and understanding of various facets of the construction process. This would enable inspectors to develop responses on a real-time basis. The resource system features will help ensure the integrity and safety of drilled shaft foundations. It is anticipated that the primary user of the tool will be the Alabama Department of Transportation (ALDOT).

2.0 Background

2.1 Purpose

This project was undertaken to develop a computer-based tool to provide training and understanding of drilled shaft construction processes to young engineers.

Drilled shafts are construction sensitive foundations and require thorough inspection. Drilled shafts are unlike driven piling, where capacity can be monitored with each blow of the hammer. During drilled shaft construction, the capacity and the integrity of the shaft cannot be readily checked as it being constructed. The inspector's job is to insure that the proper construction procedures and testing procedures are being followed. Hence, it is important for young civil engineers to know the responsibilities as well as have a thorough knowledge of drilled shaft construction.

3.0 Project Tasks

3.1 Design of web-based resource material

To create the web-based tool for drilled shaft construction inspection, it was important to pattern it after a standard construction manual. The ALDOT Construction Manual for bridge sub-structures (ALDOT, 2002) was selected for this purpose due to its accessibility. This manual is readily available online for download in pdf format at the ALDOT Homepage.

The drilled-shaft construction procedures in the ALDOT manual are presented in the section entitled "Substructures" (Figure 3-1). The drawbacks of the ALDOT Manual are that it contains mostly text with a limited explanation of the responsibilities of drilled-shaft construction inspectors. There is very little visual material to educate young engineers about construction systems and processes. No effort was made to illustrate graphically the concepts presented within the document. Without detailed explanation and graphics, young engineers are likely to dwell on questions like, "How are drilled shaft foundations installed? What equipment and procedures are used to construct a drilled shaft? What field tests are performed during drilled shaft construction?" These questions can be answered quickly by including illustrations, graphics, images and video clips.
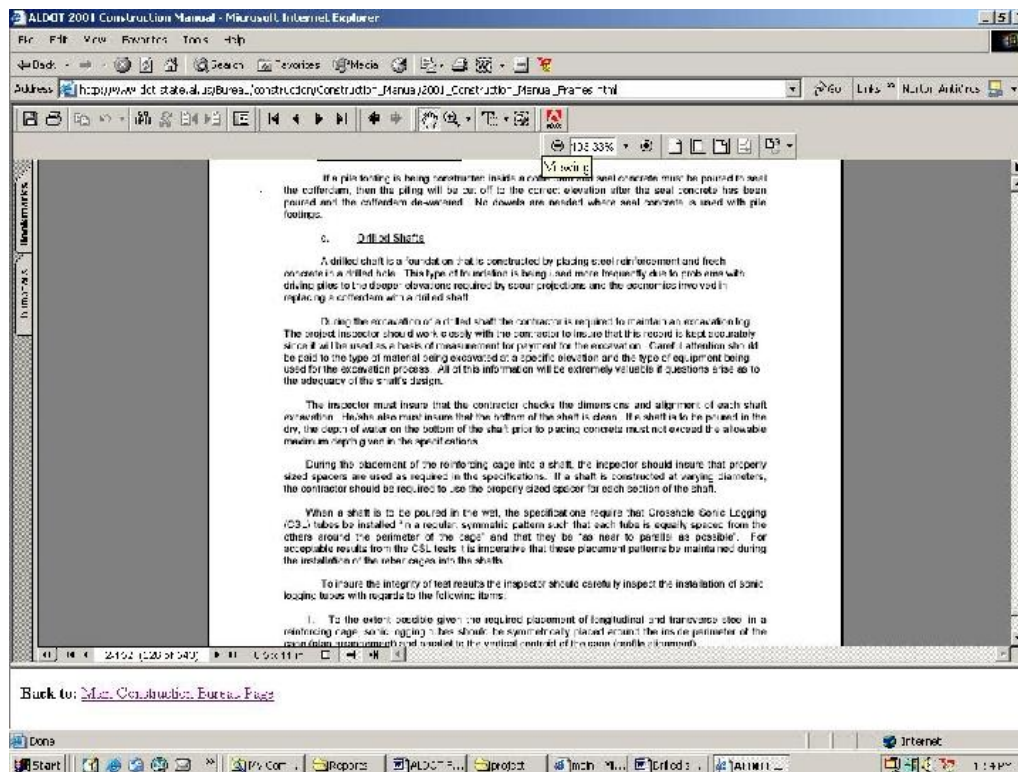

Figure 3-1. Contents of drilled-shaft construction portion of the ALDOT Construction Manual

Microsoft's FrontPage software was used to convert the drilled-shaft construction portion of the ALDOT "Construction Manual from pdf format into the web-based format, html. An html file was created for each section and subsection. These files were used to develop the resource material for drilled-shaft construction inspection. In addition, the Construction Manual, in pdf format, was included within the resource as an accessible document, eliminating the need for a user to visit the ALDOT homepage to refer to this document.

After an extensive literature review, the research staff organized the resource materials for inspection of drilled-shaft construction into the outline shown in Table 3-1. The contents listed in the table are voluminous, making it a challenge to present in a layered, user-friendly, web-based format. It was important that the user be able to navigate easily through the resource material without confusion or loss of reference. In addition to developing the web format for presenting the material, considerable effort was expended to collect, convert and organize the resource materials on the various topics.

Table 3-1 Topics in the expert system tool

I. HOME
    Purpose
        Contact Information
        Feedback

II. INTRODUCTION - This section provides definitions along with the advantages and disadvantages of drilled   shaft construction. Important duties of drilled-shaft construction inspectors are discussed.

III. CONSTRUCTION
    Types - This section involves different construction methods adopted for constructing drilled-shaft
        Foundations, with relevant photos and figures.
        Dry open hole
        Wet or slurry
        Casing method
    Requirements - This section deals with requirements for drilled shaft construction. It also provides
        information on various forms that inspectors fill out during the course of construction of drilled-shafts.
        Materials
        Equipment
        Construction requirements
    Integrity Testing - This section provides information on integrity tests performed in the lab and the field
        during drilled shaft construction.
    Monitoring - Monitoring of construction deals with the different forms and tables that inspectors fill out while
        monitoring drilled-shaft construction.
    Documentation – This section reviews different forms that are completed during the construction of drilled-
        shafts. It also provides sample forms used by DOTs.
    Image gallery - The image gallery contains photos of drilled-shaft equipment and construction techniques.

IV. RESOURCES - This section reviews terminologies and definitions for drilled-shaft construction.
    Glossary
    ALDOT construction manual
    References

3.2 Design of Web Page

Microsoft FrontPage is one of the easiest means for creating a professional web page without prior knowledge of html, largely because it has a graphical user interface. The website was created using the html files of the drilled-shaft construction information from the ALDOT Construction Manual and a few color images of drilled-shafts acquired from the Internet. It consisted of three frames: one to highlight the title, another to navigate the site and a final frame to display information.

The slide tree menu from Open Cube (http://www.opencube.com/) was selected because its features closely met the requirements. At first, Open Cube's dynamic menu tree was considered inadequate. Due to limitations of dynamic html, the slide tree menu only allowed for one submenu per main menu topic. After consulting Open Cube's technical support group, a java applet version of the slide tree menu was located. The java applet permits as many submenus as needed. The only limitation is the amount of space provided in the web design. This slide tree menu, shown in Figure 3-2, automatically closes submenus when a new topic is selected. The slide tree menu is easy to revise and edit. While java applets can be edited with a simple text editor like notepad, Open Cube offers a graphic user interface called Applet composer to edit its slide tree menu. Here the developer can make changes easily such as removal of menus or submenus. This software could be used with Dreamweaver or Frontpage.
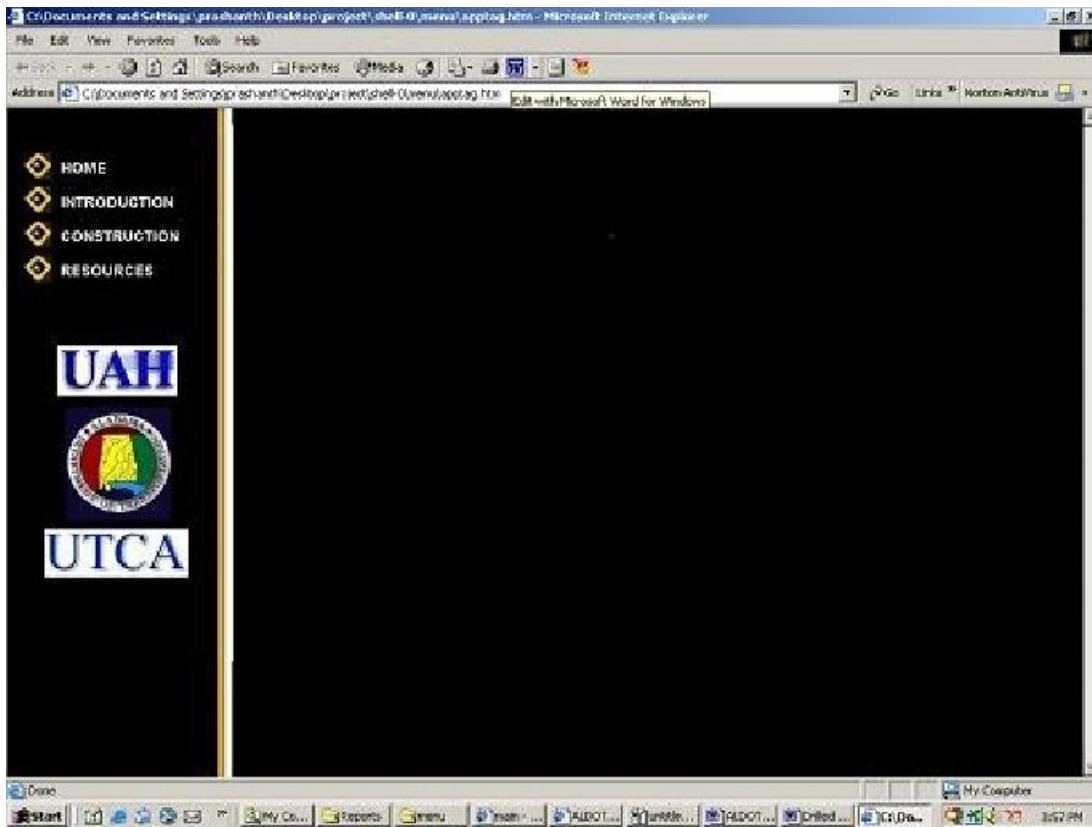

Figure 3-2 Photo showing details of the slide tree menu

3.3 Generation of Resource Material

To develop a web-based tool, it was important to collect color images and slides of drilled-shafts, components and construction processes from many sources. A variety of media including slides and color diagrams were collected from an array of Internet websites, ALDOT and other state DOTs. The electronic images were sorted based on the topics covered in the training tool. Graphics from slides and scanned images (see the examples in Figures 3-3 and 3-4) were added to the appropriate sections of the resource. Each of the major sections was provided pictures

from actual construction sites, and color slides illustrating the drilled-shaft construction process and the construction equipment/tools used in the process.
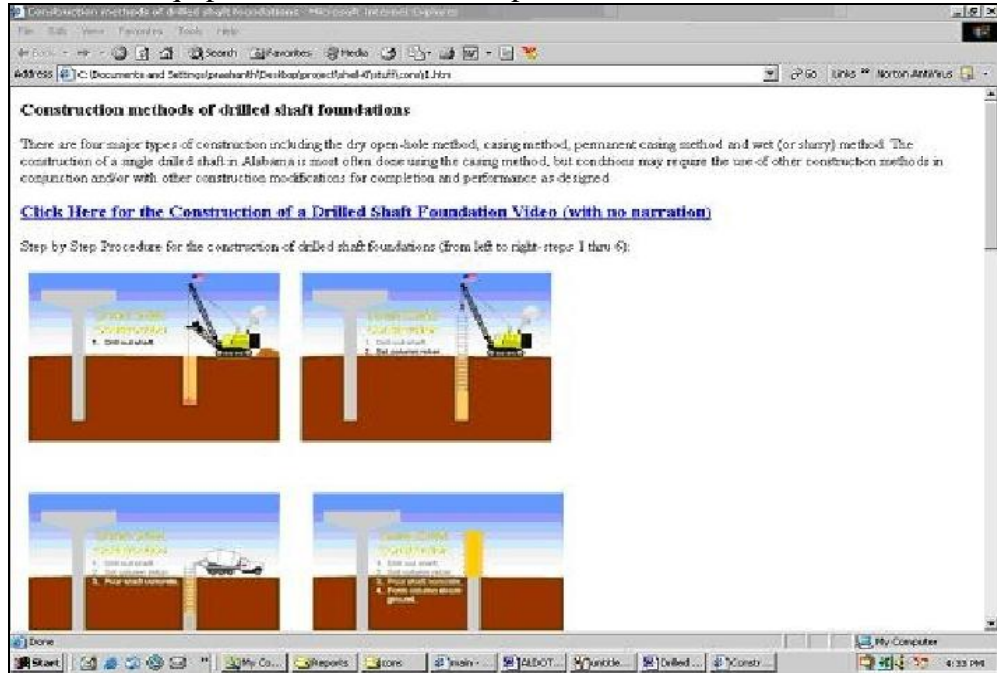

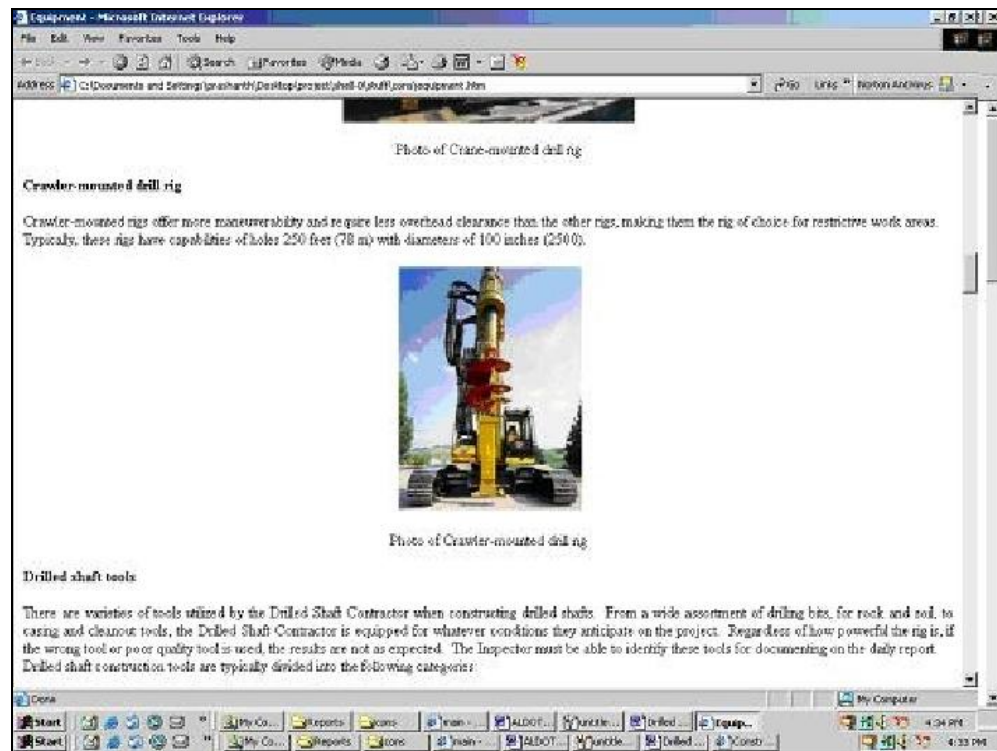**Figure 3.3 Slides illustrating a drilled-shaft foundation construction procedure**

Figure 3-4 Text illustrated with a graphic

3.4 Development of Thumbnail Galleries

Using the sorted photos, a thumbnail gallery was created and inserted in the expert system. Figure 3-5 shows a typical thumbnail gallery developed for drilled-shaft construction inspection.

Figure 3-5 Thumbnails of drilled-shaft construction inspection

The thumbnail galleries allow users to view small images on a single page. By clicking on any of the smaller images, a larger, detailed photo of the image will appear as shown in Figure 3-6.

A tool for navigating the thumbnail gallery is provided at the top of each enlarged image. The user can choose from the following options:
- Previous: click here for the previous enlarged photo in the gallery
- Next: click here for the next enlarged image in the gallery
- Index: click here for the single page view

Figure 3-6 Enlarged photo of a drilled-shaft excavation from the thumbnail gallery

3.5 Final Design of Web Page

With an elegant navigation tool that is simple to edit, the graphically illustrated Microsoft Word files were converted into web pages and incorporated into the final design of the expert system for drilled-shaft construction inspection. The final web design followed a three-frame structure. The first (top) frame serves a banner heading for the resource. The second (lower left) frame displays the slide tree menu for document navigation. The final (lower right) frame displays the contents, as shown in Figure 3-7. The initial splash screen is a rotating gallery of images displayed when the web page is accessed. As the web document is refreshed, a new image of drilled-shaft construction is shown. As a topic is selected, information is viewed on the right side. The slide tree menu automatically closes a topic when a new topic is selected.

3.5.1 Video Clips

The resource material is designed so that it can be enhanced in the future by insertion of video clips. A similar previous UTSA project demonstrated this task could be accomplished with little additional effort.

Figure 3-7 Information on equipment requirements displayed on the right side of the resource

4.0 Potential Benefits of the Project

The availability of this computer-based (resource material) tool can substantially increase the understanding of young DOT engineers for the drilled-shaft construction process and can substantially enhance their skills as designers or construction inspectors. Additionally, the resource material can be continuously improved in the future by insertion of appropriate visuals and video clips to address emerging situations and changed construction processes.

This web-based tool is a dynamic resource that can be enhanced as more resources become available. The ALDOT can install the current package and make it available to its engineers and inspectors, on-line, so that its use can be maximized.

5.0 References

5.1 Publications that Provided Project Resources

Alabama Department of Transportation (ALDOT), Construction Manual, Alabama
Department of Transportation Construction Bureau, Montgomery, 2002.

Bazant, Bazant, "Methods of Foundation Engineering", Elsevier/North Holland, Inc, 52
Vanderbilt Avenue, New York, NY 10017, 1979/

Brown, D. A. and K. W. Weinel," Guidelines for the selection, design and construction of drilled
shaft foundations for bridges in Alabama," Highway Research Center, Harbert Engineering
Center, Auburn University, Alabama, 1990.

5.2 Websites that Provided Project Resources

http://dotweb1.dot.state.ny.us/tech_serv/geo/manuals.html

http://kdot1.ksdot.org/public/kdot/burconsmain/specprov/pdf/90m-0090-r08.pdf

http://www.dotd.state.la.us/planning/geotechnical/geo_index.shtml

http://www.williamsearthsciences.com/drilled_shaft/contents.htm

http://www.dot.state.oh.us/spec/524.htm#524.02 Materials

http://www.dot.state.il.us/bridges/gbsp.html

http://www.williamsearthsciences.com/drilled_shaft/contents.htm

http://cgpr.ce.vt.edu/photo_album_for_geotech/Foundations%20-
%20Deep/Drilled%20shaft%20construction/Drilled%20shaft%20construction%20-%20main.html

http://www.clarksvillebypass.com/photo/Drilled%20Shaft%20Construction/sld006.htm

http://www.sddot.com/operations/docs/specbook/465dual.pdf

http://www.gpe.org/products/dhc.htm

http://www.dot.state.ga.us/specialsubjects/roadconstruction/sidney/approach/drill.shtml

http://www.ftba.com/ftba/bids/specs/D4551511.doc

Appendix A
Instructions for Managing the Resource Material

Instructions for modifying the home page

The homepage follows a standard three-frame html format. The code for the frames can be found in the drilledshaft.htm file folder. Using a text editor like notepad or a webpage editor like FrontPage or Dreamweaver, the drilledshaft.htm file folder can be edited.

Depending on what is being edited, modifications can be made to the following three files: Ban.htm, apptag.htm, and welcome2.htm. These files are linked within the drilledshaft.htm file. Ban.htm is the webpage for the top banner. It is located in the banner subfolder of the shell-0 folder. Apptag.htm is the webpage for the java applet of the slide tree menu. It is located in the menu subfolder of the shell-0 folder. Welcome2.htm is the webpage for the rotating gallery of drilled-shaft images. Specific modifications to these three files can be done by editing them with notepad, FrontPage or Dreamweaver

Instructions for modifying text

Most of the text in this resource comes from Microsoft Word files that have been saved as web pages. These web pages contain a significant amount of xml and cascading style sheets. Microsoft Word is the recommended text editor. While FrontPage and Dreamweaver can be used, these web page editors may have trouble interpreting xml.

To edit text within the resource, one must go to the "stuff" subfolder of the shell-0 folder. In the stuff folder, the following three folders contain the web pages for text: intro, cons and ref. The intro folder contains all of the text for the introduction. The "cons" folder contains all text for the construction section. The "ref" folder holds all of the web pages for the reference and resources. Each of these folders contains text web pages. Most of these files correspond directly to the links of the slide tree menu.

By opening these web pages with Microsoft Word, edits can be made easily. To make a specific edit to a file, the user can right-click on the text and view the source. The file can be easily found and edited in the appropriate section folder (i.e. introduction, construction, or reference).

Additions to the text can be made to the mage of Java applet editor by saving the Microsoft Word files as web pages in the appropriate section folder. After this is done, hyperlinks are created to these new files by modifying the slide tree menu. Hyperlinks are created in Microsoft Word by highlighting the text and clicking Insert Hyperlink from the menu bar.

It is not necessary to edit subfolders that correspond to the labeled web pages of text. These folders contain the images used within the text.

Instructions for thumbnail galleries

The first step to create the thumbnail gallery is to collect all of the images that are to be used into one folder. These files need to be in either png or jpeg format. A list of subtitles for each picture is created and saved as a text (.txt) file using Microsoft Word, notepad or your favorite editor. Each subtitle should be separated by a blank line and follow the order of pictures listed in the folder. There should be no blank lines at the beginning of this text file. This text file should be saved in the same folder as the images. If confused, use one of the text files in a current thumbnail gallery as an example.

A perl script was written to create a thumbnail gallery. For this program to work, perl script compiler software must be installed on the computer, if not already present. This software is free and can be downloaded and installed from activestate.com, using the following link; http://www.activestate.com/Solutions/Programmer/Perl.plex

Click "download" at the bottom of the page for Active Perl (free binary version distribution of Perl for Windows) and install the appropriate version for your operating system. After installation, copy the thumbail.pl file from one of the current thumbnail gallery folders into your new folder and double-click it to run. An MS_DOS window should appear asking for the name of the text file created earlier. Enter it. You should be prompted for the title of the new thumbnail gallery. Enter it. Your new folder should contain an instant thumbnail gallery with a webpage for each image. Double click the thumbnails.htm file. You should see your new instant thumbnail gallery in your browser.

The final steps are to save the new thumbnail gallery folder in the appropriate section of the resource. Create a hyperlink to the new thumbnails.htm file within the text using Microsoft Word, and add the appropriate link to the slide tree menu.

Other methods for creating thumbnail galleries can be used because this feature is available in recent versions of web design software like FrontPage.

Instructions for modifying the slide tree menu

The slide tree menu is the java applet version from Open Cube Software. It can be easily downloaded for evaluation from Open Cube's homepage (www. Opencube.com). (Note: A purchased license from Open Cube is required to legally display the slide tree menu within a website on the internet) This software is fully supported and specific questions on modifying the slide tree menu can be directed to Open Cube's technical support group.

Modifications to the slide tree menu are not difficult, but are better explained by demonstration than by written instructions. The first step is to download Applet Composer from the Open Cube homepage, at http://www.opencube.com/prod_composer.html. Then click on the proper operating system in the lower right corner of the webpage. After installing the software on your computer, read all of the instructions for editing and modifying Open Cube menus.

Next, double-click the applet composer icon. On the "select new applet" menu, click "cancel. "Next, click on "file-open" and look in the shell-0 folder for the menu subfolder. From the menu subfolder, open the "apptag" webpage. All modifications to the slide tree menu are made by editing the apptag.htm file. Once this file is opened, you should see an image of the slide tree menu for the resource within the applet composer. Make edits to the general applet by changing the options listed in the box in the lower left corner. Specific applet settings can be changed using the options in the box in the lower right corner.
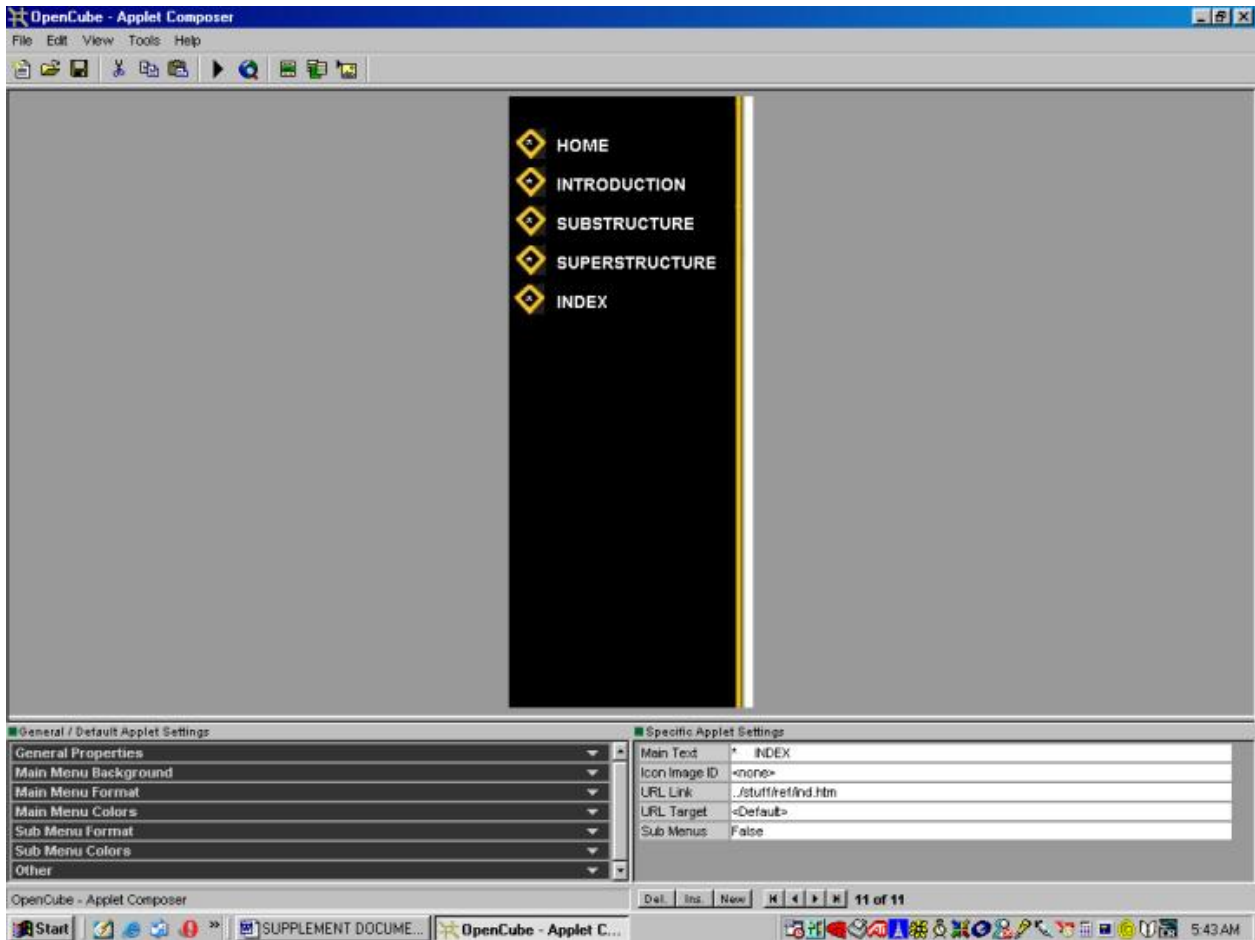

Figure A-1 Image of java applet editor

Main menus can be added and edited by using the arrow keys in the lower right corner. To edit a subfolder, click on "submenus" then click the "…" icon. A submenu builder window should appear. Do not pay any attention to whether the "submenus" is set to false or true.
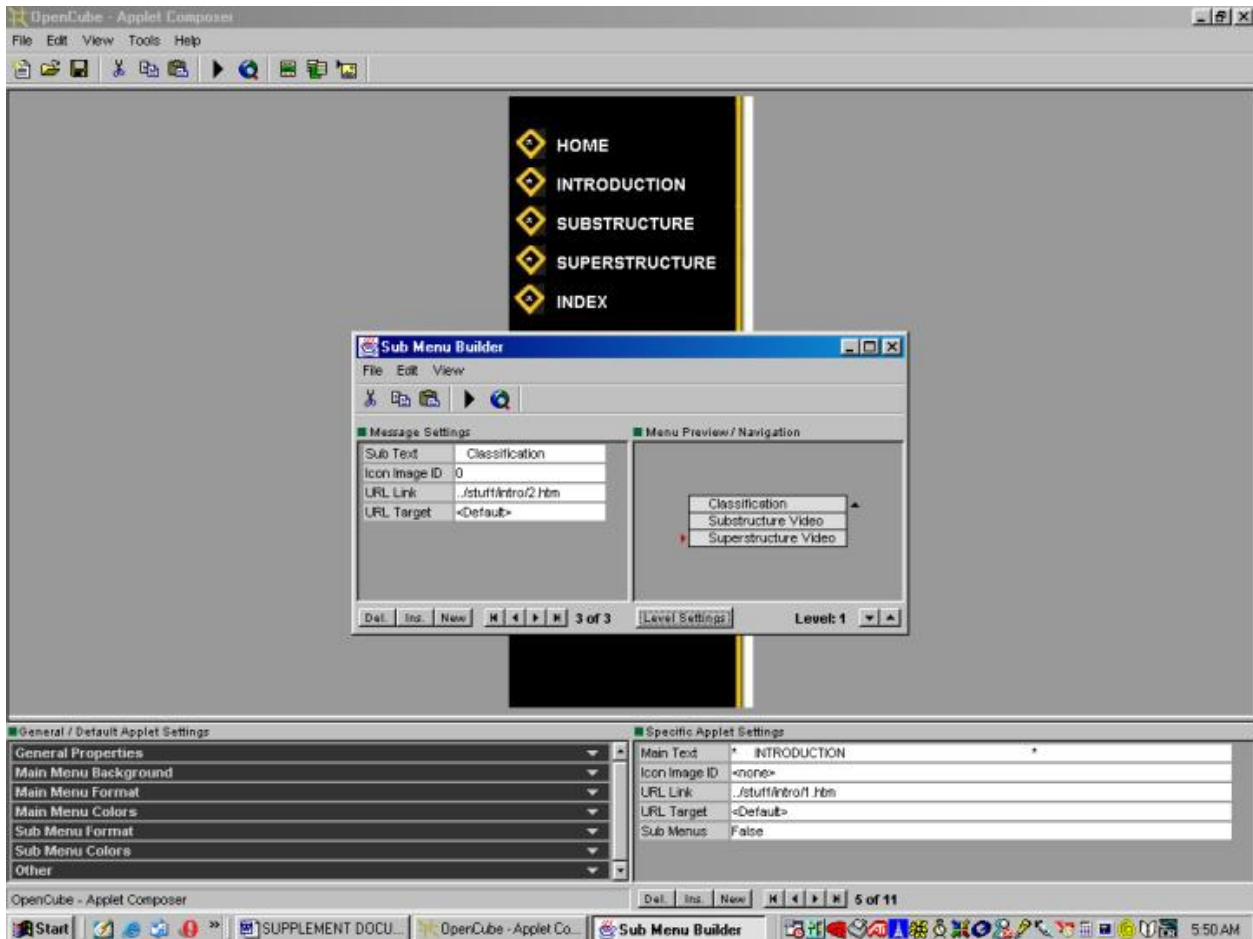
Figure A2- Image of submenu builder

Edits are made to the submenu folders by changing the options displayed on the left side. By clicking on the link names, the user can navigate through the slide tree menu and make further changes in the appropriate places. Option buttons for deleting, inserting, and creating new links are provided in the lower left portion of the screen. Most of the edits are self-evident in this graphic user interface. It is important that the pathways for the URL links are typed in correctly, or the slide tree menu hyperlinks may not function properly. Save all changes made to the slide tree menu. Preliminary testing of the slide tree menu can be performed by clicking the arrow key displayed on the top menu bar.

Note on using the applet composer

The applet composer used in this project is version 2.0, and some software bugs may still exist. The most notable of these is the creation of submenus. Sometimes the template of a submenu exists even though the composer states its existence as false. It is important to check the slide tree menu for any extraneous submenus. If any are discovered, go to that submenu in composer and click on "false" and the "…" icon. Once inside the submenu, click the delete button in the lower left corner.

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Instructions for inserting logos in the slide tree menu

Changing the background image of the slide tree menu is fairly simple. Use the previous directions for the applet composer and open the apptag.htm file. In the lower left corner of the main screen, select "main menu background." Click on "BG Image," click the "…" icon, and hyperlink to the appropriate image. For this project, two background images were created: Image5.jpg and Image5a.jpg (in the menu subfolder). Image five does not contain logos for the slide tree menu. Image five has the logos.

If further editing of these images is required, edit these jpg files using a photo editor such as Paint Shop Pro or Adobe Photoshop.

Instructions on the feedback page/search

The feedback page is an html page. It can be easily edited using note pad or another web page editor such as FrontPage, Dreamweaver or Microsoft Word. The file to edit is the feed.htm file located in the "welcome" subfolder. The search index is also an html page. The file to edit is the "search.htm" file located in the "ref" folder of the stuff "subfolder."

Drilledshaft.htm

The "drilledshaft" is the html code that links to everything within the resource. It can be edited using a simple text editor like Notepad or a more sophisticated web editor like Microsoft's FrontPage or Macromedia's Dreamweaver. The code consists of a standard three-frame format. The top frame is linked to the "ban.htm" file for the banner. The next two frames are for the resource's slide tree menu and view screen. The slide tree frame is linked to the "apptag.htm" frame. The default view screen is linked to the "welcome2.htm" file, which is for the rotating gallery of drilled-shaft images.

Shell-0 folder

This file folder contains all of the material necessary for this resource. It contains five file folders named: banner, menu, stuff, thumb, and welcome. The banner folder contains all of the information for the "expert system for drilled shaft construction inspection" heading. The menu folder holds all of the necessary files for the slide tree menu. Stuff contains all of the Microsoft Word files on drilled-shaft construction that have been converted into html. The thumb folder holds all of the images for the thumbnail galleries. Welcome contains the code and images for the rotating gallery of drilled shafts.