

Teaching Design of Formworks for Concrete using 3-D Animated Free-body Diagrams

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Abstract

Structural analysis and design concept visualization, whether in reinforced concrete permanent or temporary structure (formworks) is a subject that depends on geometric and physical perception, and every effort should be made by educators to enhance this ability. This makes it an interesting challenge in an exciting area, requiring creativity, imagination, as well as knowledge, and systematic thinking. Although the classroom environment in Engineering and Construction Science is highly structured by the instructor, teaching students to be critical thinkers is essential in the virtual classroom of the future. The objective of this research was to develop a 3-D animation and walkthrough model with 3-D animated free-body diagrams to teach design for formworks for concrete. All the techniques that were used in this research employed a generic programming architecture, which was discipline independent and could be adapted to any other similar domain. These visualization techniques can be valuable aids not only in teaching in the classroom but also as an effective self-directed tool for open learning via the web.

Introduction

In the design of reinforced concrete structure, formwork design plays a crucial role. It is very important for a designer to consider economy while planning the formwork for the reinforced concrete structure. Efficient and economical use of the material of which the forms are built is an integral part of the design process. The forms for a concrete structure may cost more than the concrete or the reinforcing steel; and, in some instances, they may cost more than the concrete and the reinforcing steel together (Peurifoy, 1976). The cost of formwork is significant, generally amounting to anywhere from 40% to 60% of the cost of a concrete structure. Selection of materials suitable for formwork should be based upon maximum economy to the contractor, consistent with safety and the quality required in the finished work (Hurd, 1995). Formworks are subjected to maximum stresses for relatively short periods of time. Wood is capable of absorbing large overloads if the stresses are of short duration, and this is true of formwork (Peurifoy, 1976). Lumber was once the predominant form material. However, nowadays the most commonly used

job-built concrete formwork materials include timber, plywood, and hardboard. Some of the most commonly used timber for concrete formwork are Douglas fir-larch, Douglas fir-South, Hem-fir, Spruce-pine-fir, and Southern pine. Plywood is commonly used for sheathing or lining forms because it gives smooth concrete surfaces.

As technology rapidly changes, the importance of educating and training diverse populations of civil/construction engineering/science students becomes more critical. With the advances in information technology (IT) over the last decade, the traditional teaching format of having an individual lecture to an audience has been supplemented, and in some cases, replaced by the rapid development and implementation of new distance learning methods. Classroom use of IT for teaching science, engineering and technology has increased dramatically in recent years and has proved to be very effective in various situations (Haque 2001, 2003). Contemporary applications of IT allow us to develop learner-centered virtual design studios that can be reached to a large student population via the web. Enhancing World Wide Web developments, the new opportunities for interactivity and flexible access to various media format (text, sound, static illustrations, 2D and 3D dynamic illustrations, Virtual Reality worlds) challenge the traditional experience in shaping learning environments for web-based education (Klett, 2002). The student-centered distance-learning archetype should include dynamic demonstration of theoretical engineering models allowing students to manipulate, experiment, and translate theories into real-world applications. Visualization is an important factor in modern education. Traditional lecture format teaching methods sometimes fall short of conveying the complex analysis and design principles that need to be mastered in reinforced concrete design course. One of the methods of reducing this short fall is to use simple animated virtual models, which demonstrate basic structural design concepts that can be used to enhance the students understanding. The interactive computer aided learning (Haque 2001) allows students to proceed at their own pace, motivated by a curiosity about “what happens” interactivity and “the need to know” the design/analysis principles.

McManus, and Segner (1991), are of the view that visualization will take many forms in the construction industry. The generation and manipulation of three dimensional models of a proposed project using sophisticated three dimensional modeling techniques to hypothetically build and test a facility while it is still in the design development stage is one of the important uses of visualization. Senior designers, construction managers, and client specialists use the model to "visualize" both the construction and operation of the facility. Critical interferences are prevented; inefficiencies are minimized; errors are corrected in magnetic memory rather than in steel; and client decision makers are duly impressed. Superintendents can even finish a job with single digit revision numbers on their drawings.

As the global community increases its utilization of new technologies in the distribution and acquisition of knowledge and information, new paradigms in engineering and management education emerge. A successful engineering and management education model must include and initiate new and diverse methods in order to effectively determine and address the current and

forthcoming needs in the training of engineers and managers (Motlagh, and Shahir-Motlagh, 2002).

Hence it is increasingly becoming important to develop a web based 3-D visualization and animation to explain the various construction processes. The objective of this study is to develop a web-based 3D animation and walkthrough of the design and construction processes for formworks for reinforced concrete construction.

Visualization and Animation Techniques

The visualization techniques that are used to develop a web-based design and construction process visualization are broadly classified under the following categories:

1. Image visualization/Animation
2. Interactive flow-chart based analysis/design
3. 3ds Max based Design Animation and Walkthrough

The image visualization and animations are powerful tools for teaching design courses. If a student has a difficulty with an analysis and design problem, the animations of the structural response to loads and the 3-D animated free-body diagrams explicitly show the foundations of the design mechanics by showing the connectivity between cause and effect. This technique was used to show and calculate the loads distributed from plywood sheathing to studs/joists, stringers/wale, shores and lateral bracings. Figure 1 shows a 3ds Max screen to create animation and walkthrough. Figures 2-5 show some of the animated formwork construction details created using 3ds Max.

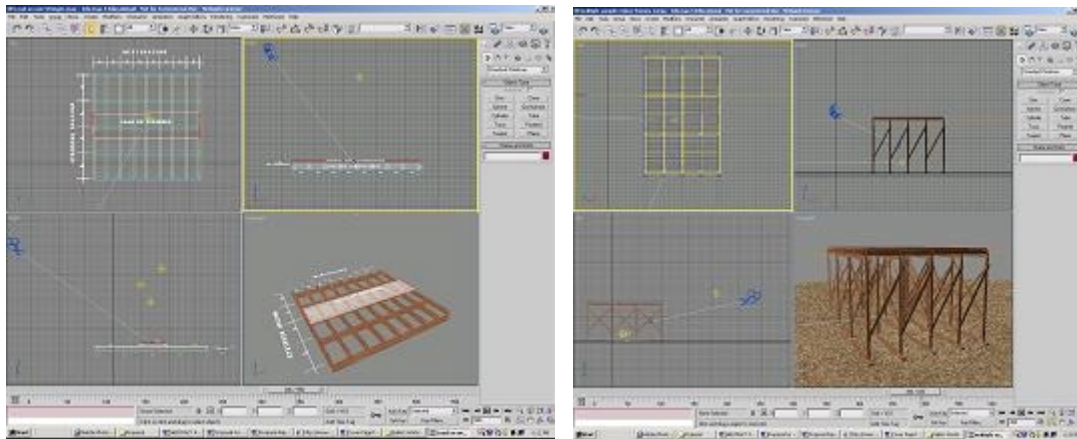


Figure 1: 3D MAX Environment to Create 3D Animation and Walkthrough

3ds Max is a fascinating 3D movie making software. With 3ds Max, one can create 3D environments and characters, objects and subjects of any type. One can arrange them in settings and environments to build scenes as desired. One can animate the characters, set them in motion as required. One can then shoot movies of the whole virtual setting. Some of the important features and functions that can be controlled using 3ds Max to create a realistic 3D animation model include assigning materials to objects, providing lights, positioning cameras, animation and rendering. Some of important features in 3ds Max that were used in this research are:

- In 3ds Max material editor was used to design materials and maps to control the appearance of object surfaces. Maps were used to control the appearance of environmental effects such as lighting and background.
- Lights in 3ds Max includes the following standard light types: omni, spot, and directional lights. One can set a light to any color and even animate the color to simulate dimming or color-shifting lights. All of these lights can cast shadows, project maps, and use volumetric effects.
- Cameras in 3ds max - One can create and place cameras as desired using 3ds max. Cameras define viewpoints for rendering, and one can animate cameras to produce cinematic effects.

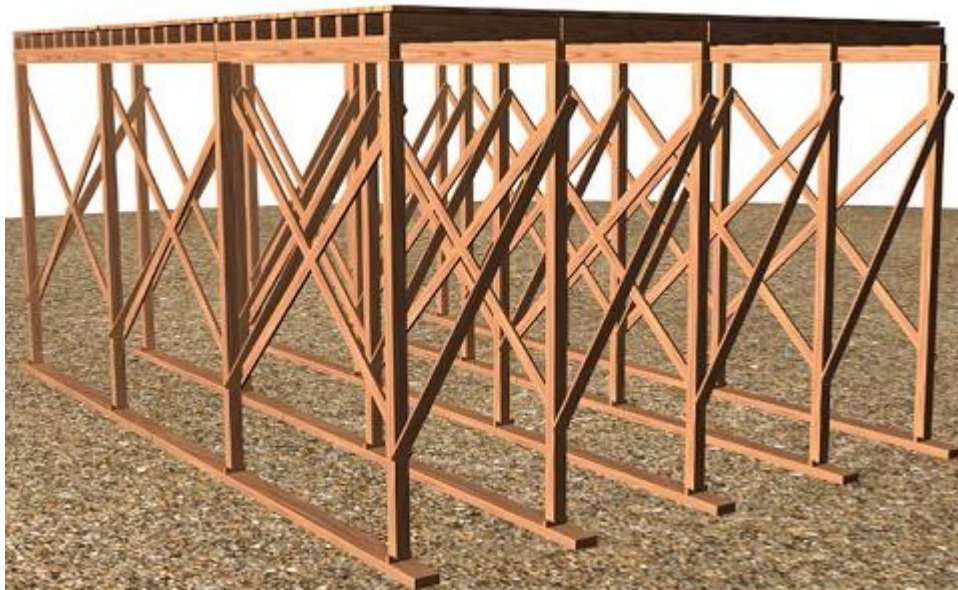


Figure 2: Timber Formwork for Reinforced Concrete Slab

- Animation in 3ds max - One can animate the position, rotation, and scale of an object, and almost any parameter setting that affects an object's shape and surface. One can link objects for hierarchical animation, using both forward and inverse kinematics.
- Rendering in 3ds max - One can use the rendering features to define an environment and to produce the final output from a scene. One can render a single image by setting the 'renderer' to render a single frame of an animation. One can specify what type of image file to produce and where the program stores the file. Rendering an animation is the same as rendering a single image except that one can set the 'renderer' to render a sequence of frames. One can choose to render an animation to multiple single frame files or to popular animation formats such as .flc or .avi.

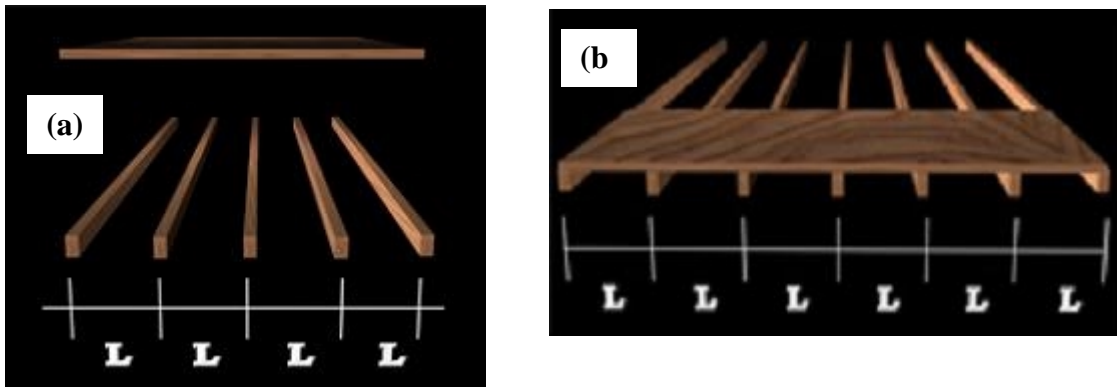


Figure 3: (a) 3-D Animation showing the Timber Joist Spacing in the case Plywood Sheathing Bending Parallel to Face Grain; (b) 3-D Animation showing the Timber Joist Spacing in the case Plywood Sheathing Bending Perpendicular to Face Grain.



Figure 4: 3-D View showing the load on each timber stringer

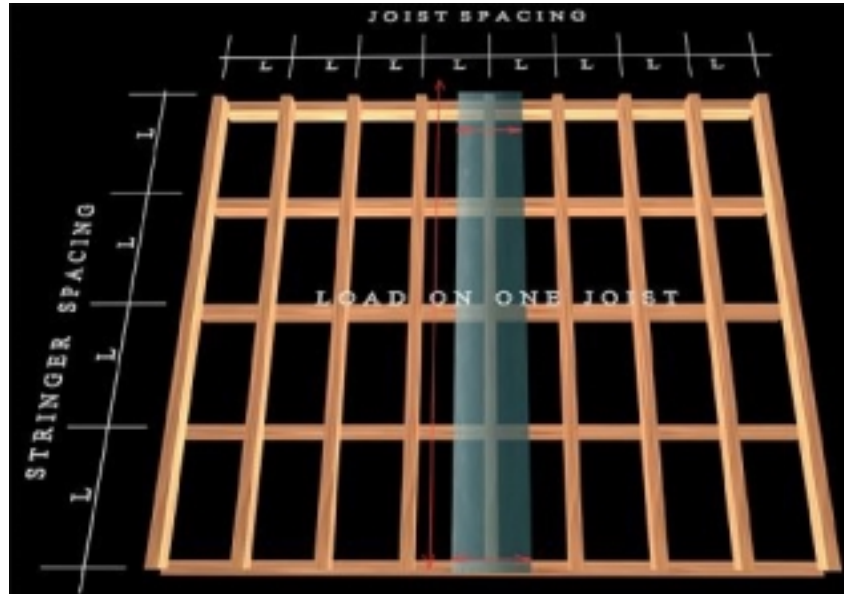


Figure 5: 3- D View showing the load on each timber joist

The manipulated digital images are powerful tools for teaching design courses. If a student has a difficulty with a complex problem, these annotated versions of manipulated images explicitly show the foundations of the design mechanics by breaking up the problem into their natural components, and showing the connectivity between those components.

The flow charts are easy to follow for students. In this research, a new approach to teach structural analysis and design of concrete forms using interactive flow charts drawn on Excel spreadsheets with 2D and 3D diagrams embedded or linked and other visualization models including walkthrough hyperlinked to the flowcharts.

A website was developed using Microsoft Front Page. The components of concrete formwork designed were listed and linked to the animated 3-D models and an Excel spreadsheet for the computation of loads, selection of various timber members and calculations of their spacing. The students will have to follow the links and obtain the required results. Figures 6-8 show some of WebPages.

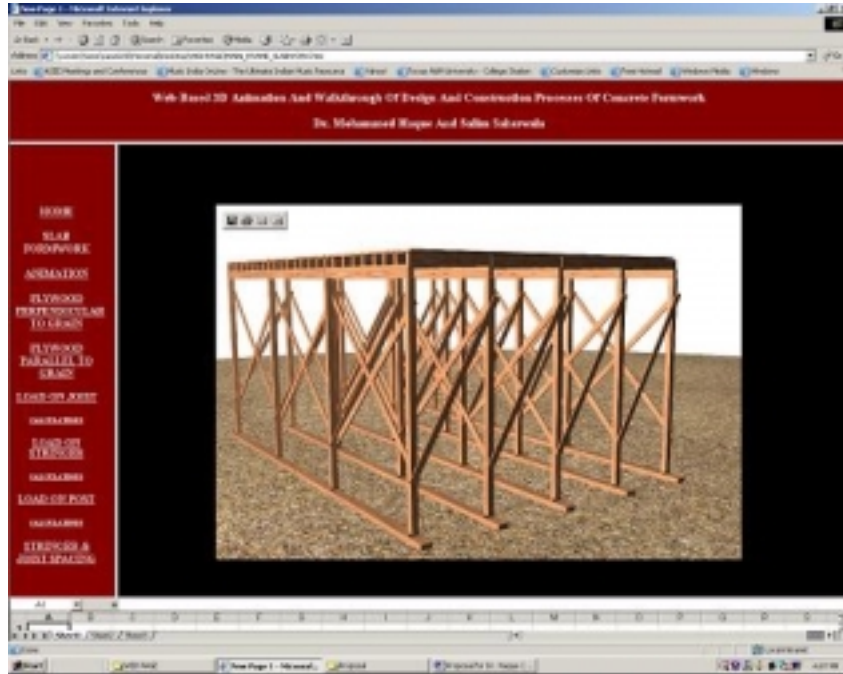


Figure 6: Web page showing the main page of the computer interface

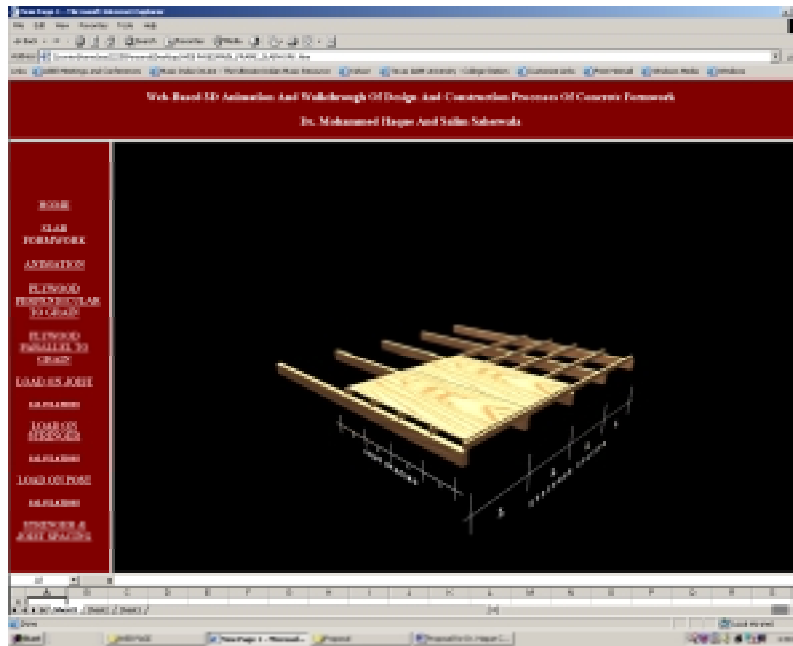


Figure 7: Web page showing the 3-D model of the spacing required for the joist

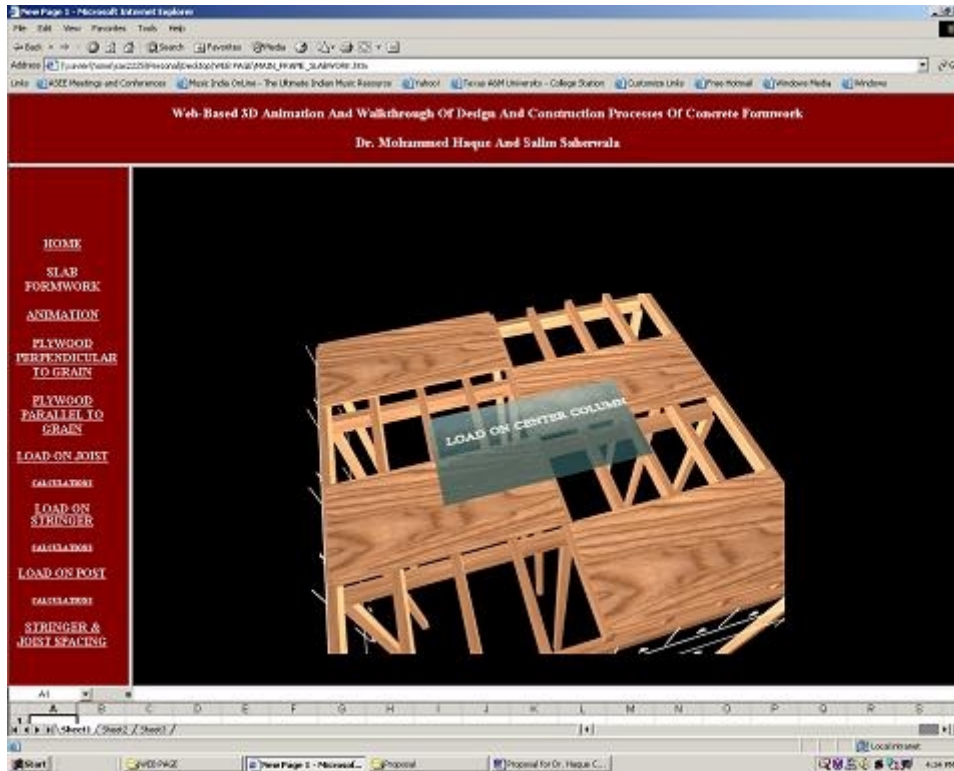


Figure 8: Web page showing the 3D model for calculating the load on each post.

Concluding Remarks

This paper describes a web-based 3D animation and walkthrough model for design and construction processes for formworks for reinforced concrete construction. The website will help construction engineering/management students to better visualize the analysis and design sequence of operation for concrete formworks for structural slab, beam, column and wall. This interactive model will help students to visualize and participate in analysis and design of concrete forms.

Considering the interest of youths in computer games these days the use of a 3-D computer animation model will develop a lot of interest amongst them and will motivate them to try to better understand and retain important concepts of design and construction management of temporary structures for reinforced concrete construction.

All the techniques that were used in this research employed a generic programming architecture, which was discipline independent and could be adapted to any other similar domain. These visualization techniques can be valuable aids not only in teaching in the classroom but also an effective self-directed tool for open learning via the web.

References

1. AbouRizk, S. M., & Sawhney, A. (1994). Simulation and gaming in construction engineering education. Paper presented at the American Society for Engineering Education conference. Retrieved Aug 1, 2003, from www.informs-cs.org/wsc98papers/179.PDF
2. Haque, M.E. (2003). Visualization Techniques for Structural Design Education, Proceedings of the American Society for Engineering Education, 2003 ASEE Annual Conference, Session 2158, Nashville, TN.
3. Haque, M.E. (2001). Web-based Visualization Techniques for Structural Design Education, American Society for Engineering Education, 2001 ASEE Annual Conference Proceedings, Section 2793 Multimedia, Albuquerque, NM. Retrieved from http://www.asee.org/conferences/search/01143_2001.PDF
4. Hurd, M.K. (1995). Formwork for Concrete (6th Edition.), Special Publication Number 4, American Concrete Institute: Farmington Hills, MI, USA.
5. Klett, F. (2002), Designing a virtual learning space with 3D real-time presentation and advanced navigation, the 32nd ASEE/IEEE Frontiers in Education Conference Proceedings, session S2E, Boston, MA.
6. McManus, W., & Segner, R. (1991). Hypermedia in Construction Education. Paper presented at the Associated Schools of Construction conference. Retrieved Aug 1, 2003, from <http://asceditor.unl.edu/archives/1991/McManus91.htm>
7. Motlagh, B., & Shahir-Motlagh, M. (2002). Redefining Traditional Methods in Engineering Education in the New Millennium. Paper presented at the American Society for Engineering Education conference. Retrieved Aug 1, 2003, from http://www.asee.org/conferences/caps/document2/2002-757_Paper.pdf
8. Peurifoy, R.L. (1976). Formwork for Concrete Structures (2nd Edition). McGraw Hill, Inc, USA.

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