

An Expert System Based Conceptual Design of Bridges: An Overview

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ABSTRACT: An Expert System is an intelligent interactive Computer program which should emulate an expert and provide an advice that requires vast experience in a particular domain. Expert system has been applied to a number of civil engineering design problems, such as high rise buildings, offshore structures, industrial buildings and bridges. In this, Bridges are the prime example of the type of structures where conceptual design is of importance, and hence there is great scope and need for development of knowledge based expert system (KBES) for assistance in preliminary design stage of bridges. A critical review on the development of expert system for conceptual bridge design is presented in the proposed paper. This paper gives an idea about a Development of Expert system like BRIDGE LEAP for the Conceptual Design of Bridge. This Paper covers an application of Expert System-Bridge LEAP to PSC Box Girder bridges.

Keywords - Knowledge based expert system (KBES), Bridge, pre-stressed concrete, Bridge LEAP.

I. INTRODUCTION

A Bridge is a Structure which covers a gap between two piers. It is an arrangement made to cross an obstacle in the form of river, valley or another roadway or another railway etc. The bridge structure mainly comprises of three parts: Superstructure, Bearing & Substructure. Superstructures resist its self weight, moving load & transmit it to the bearing. The bearing will receive point load & evenly distributed to the substructure. & then substructure transmits that load to strata through foundation.

Bridges are broadly classified based on various criteria like: flexibility of superstructure as fixed span bridges or Movable bridges, Position of bridge floor relative to the formation level and the highest flood discharge as deck bridges, through bridges or semi-through bridges, Inter-span relations as simple, continuous or cantilever bridges, & On Span criteria basis also. Many of the existing Expert system for bridge designs is based purely on heuristic rules.

II. AN EXPERT SYSTEM

The expert system is the system that provides for solving problems in a particular application area by drawing inferences from a knowledge base acquired by human expertise. It is knowledge based program that provides “Expert quality” solutions to problems in specific domain. Expert system has been applied to a number of civil engineering design problems, such as high rise buildings, offshore structures, industrial buildings and bridges. In that, Bridges are prime example of the type of structures where conceptual design is of importance, and hence there is great scope and need for development of knowledge based expert system for assistance in preliminary design stage of bridges. Analysis of Bridge structures is well understood by some practising engineers & students. It is the process of evaluating the performance of known structure under the action of given loads & constraints.

The design of bridges consists of three different stages like, Conceptual design stage, Preliminary design stage & Detail design stage. Generally, An Expert system is required in the preliminary design stage only.

Conceptual design stage: It is the early stage of the design process which deals with conception of structural layout and the form of construction. This stage involves dialogue/communications between the clients, architect and designers. A small amount of experience plays a good role in achieving it.

Preliminary design stage: It involves the selection of overall structural form of the artifact. In this, human experience plays a significant role at this stage. Decision taken here is based on criteria to be satisfied at detailed design stage. Similarly, the decisions at the detailed design stage are governed by the parameters chosen at the preliminary design stage. Good expert system thus integrates the preliminary & detailed design.

Detailed design stage: It involves detailed analysis of the chosen structures from the preliminary design. This process involves three stages:

- a) Analysis of chosen structures.
- b) Sizing and proportioning of the components.
- c) Checking all applicable design constraints.

There are many advantages of using an Expert System like, better quality solution, better decision making expert system & Increase in project efficiency. There are some limitation of using an Expert system like, it is not capable of producing independent decisions, their application is limited to strictly areas, does not work when any information falls outside the boundary.

III. LITERATURE REVIEW

Expert system technology has been successfully applied to bridge design by several groups of researchers. The design process involves many decisions that are based on past experience, analysis, rules of thumb and other factors. Also, since a design can be done in many alternative ways, expert systems developed for bridge design may provide the most appropriate method that can be used for these structures.

Biswas and Welch (1987) developed a Bridge Design Expert System (BDES) for the design of superstructure for small to medium span highway bridges in USA. The principles of artificial intelligence have been used to develop this system. This system designs superstructures like structural steel girders and pre-stressed concrete girders of span up to 60m only.

Spencer, W.J., et al. (1989), used EXSYS, A general expert system which runs under MS-DOS for the development of expert system for preliminary design of bridges. It covers Small to medium span type bridge, Box & pipe culvert. The Knowledge base includes Road & bridge design manual, Bridge design specifications, relevant codes & documents.

Moore and Miles (1991) described the development of a use oriented knowledge based system (KBS) for the use in conceptual design of bridges. This system developed for additional aspect like. selection of supporting structures, number of span, type of foundations. But, this system was not able to design Rail over bridges or Road over bridges having more than 4-spans.

Choi et al. (1993) developed an expert system SUPEREX for the selection of superstructure type for bridges based on theoretical design criteria, mechanics of structural elements, and heuristic knowledge of experts.

Hammad et al. (1993) developed an integration of Geographic information system (GIS) with an expert system which helps to analyze the topography of bridge site. A Prototype system for the planning of the road network using GIS help at the planning level.

Burgoyne and Sham (1997), described the application of expert system to pre-stressed concrete bridge design. It covers selection of the type of bridge structure to be adopted which falls within the conceptual phase of the design procedure. It also covers selection of pre-stressing methods, cross section shapes & method of construction.

Qiang, S., Gong, H. (1991) developed an Expert system ES-PDLB for preliminary design of long-span bridges. This design projection will include bridge type, span layout, dimensions of each cross section, and the construction method. The bridge type portion (Module) has been divided into 7 categories: simply-supported concrete beam, simply-supported steel truss, continuous concrete beams, continuous steel truss, arch, cable stayed bridge, and suspension bridge. Different construction methods are suggested based on the bridge type, construction speed and equipment etc.

IV. DEVELOPMENT OF AN EXPERT SYSTEM (CASE STUDY)

Over 20 years Bentley's LEAP Bridge Enterprise developed an Expert system named as "BRIDGE LEAP". As the "BRIDGE LEAP" is most widely used computer tool used for Analysis & design of small to medium span Road concrete bridges in United State (USA). LEAP Bridge handles design of the superstructure, substructure, and geometry & it is carried out in a single interface, using three different modules that share a common interface. Basically, it acts as an All-in-One Concrete Bridge Analysis and Design.

LEAP BRIDGE consists of three modules namely

LEAP CONSPAN

It is used to analyze and design precast pre-tensioned girders of various shapes such as I-girders, box beams – adjacent or spread, open box beams, and Tee beams.

LEAP CONBOX

It is used to analyze and design complex cast-in-situ reinforced concrete/post-tensioned box girders, T beams and slab type superstructure. The bridge can be simple-span or multi-span.

LEAP RC-PIER

It is used to analyze and design intermediate piers, abutments, and footings. The different pier types that can be analyzed and designed are drop cap, hammer head and integral pier. Column arrangement can be a single column or multicolumn with different shapes namely circular, rectangular, tapered etc. The program very well handles pile cap and stem wall type of abutments. Footing types that are included in the program are isolated (rectangular and square), combined (rectangular, trapezoidal and strap), pile, well foundation and drill shaft foundation.

LEAP Bridge supports Indian (IRC), American (AASHTO) and Canadian (CHBDC) codes for analysis and design of bridges.

V. APPLICATION OF AN EXPERT SYSTEM: LEAP BRIDGE BACKGROUND

The Thane-Bhiwandi-Wadapa Road is an important link joining Thane and Bhiwandi and provides access to many villages. The project was undertaken by Maharashtra Public Works Department (PWD) who awarded the project to Supreme Infrastructure India Ltd. One of India's leading infrastructure companies. Supreme Infra appointed S.N. Bhohe and Associates, Navi Mumbai as the structural consultant to design the bridge.

Design Input Data

Overall length of Bridge = 546 m
Number of Span = 13
Typical Span Length = 42.5 m
Number of Lanes = 3
Bridge overall width = 12m
Carriageway width = 11m
Cross section type = PSC Trapezoidal box girder
Type of Stressing = Post-tensioned
Cable Type = 19 T 13

Challenges/Difficulties In Bridge Design Using Conventional Method

- 1.1 Modeling of Varying Cross sections along span on Software like STAAD.
- 1.2 Calculation of Cross sectional property.
- 1.3 Calculation of Bending Moment & Shear Forces based on ILD concept.
- 1.4 Calculation of pre-stressing Losses as per IRC-18-2000 as per given cable profile.
- 1.5 Interpretation of Analysis results using Excel spreadsheets.

Use Of An Expert System: Bridge Leap

- 2.1 Modeling of varying cross sections of Bridge to achieve economy in overall project.
- 2.2 It can auto-calculate the self weight, Cross sectional properties based on the different cross sections.
- 2.3 LEAP Bridge is having a vehicle library with predefined IRC vehicles (Class A, Class B, Class AA, and Class 70R) as per Section 207, IRC 6-2000. The software automatically selects the appropriate design lane configurations for Class A+70R vehicles per Table 2, IRC 6 based on carriageway width.
- 2.4 Bridge LEAP provides a library with different types of tendons; custom tendons can be added to the library. Tendons can be assigned at different heights of the cross-section as per required profile.
- 2.5 It can auto-calculate the Pre-stressing losses as per IRC-18-2000.

Advantages Of Bentleys Expert System: Bridge Leap

- 3.1 Rapid design resulting in saving of precious engineering hours.
- 3.2 Ease of performing design optimization to come up with economical designs saving money.
- 3.3 Ability to respond to design changes in a timely manner.
- 3.4 Standardization of design methods across the company in India.
- 3.5 Relief of the tedious and complex task of validating, securing, and updating the various spreadsheets and other in-house design tools maintained by all engineers.

VI. SUMMARY AND CONCLUSION

This paper provides a review on the development of expert system for the conceptual design of bridges. From the case study reported here, it is observed that the development of Expert system-BRIDGE LEAP shall definitely help to improve preliminary analysis & design of

- a. Pre-tensioned I-girder using CONSPAN module.
- b. Post-tensioned I-girder, Box-girder using CONBOX module.
- c. Hammer head RCC pier using RC PIER module.

Development of Expert system shall help to improve standardizes bridge design practice across the company in India. From the review of the literatures, it has been seen that, In India there is very less work reported on the development of expert system for conceptual design of bridges. Hence, there is wide scope of the development of expert system with some expert bridge engineers. This will definitely help the fresh bridge designers to use expert knowledge at the preliminary design stage, which may reduce overall design space.

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