Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 83 (1999)

Rubrik: Session 9: Information technology

Design of Computer Support for Field Operations

James H. GARRETT, Jr.
Civil & Environ. Eng.
Inst. Complex Eng. Sys.
Carnegie Mellon Univ.
Pittsburgh, PA, USA

Douglas M. SACKIN
Civil & Environ. Eng.
Carnegie Mellon Univ.
Pittsburgh, PA, USA

Daniel P. SIEWIOREK
Electrical & Comp. Eng.
Carnegie Mellon Univ.
Pittsburgh, PA, USA

Asim SMAILAGIC
Computer Science
Carnegie Mellon Univ.
Pittsburgh, PA, USA

Jason K. SMALL
Electrical & Comp. Eng.
Carnegie Mellon Univ.
Pittsburgh, PA, USA

Jirapon SUNKPHO
Civil & Environ. Eng.
Carnegie Mellon Univ.
Pittsburgh, PA, USA

Field personnel, such as bridge inspectors, crane operators and structural welders, often operate in harsh environments where their hands must be free for personal safety or equipment operation. In these situations, the efficiency and quality of field operations are limited by the operator's difficulties in accessing information and understanding the environment. Appropriate computing support can improve field operations by addressing these problems. In these projects, computers were used to provide relevant information, sense and visualise the operating environment, and communicate with remote locations.

It is important that the application of computing support be a step forward for the task and the operator. It is not sufficient to put a desktop application on a portable computer for field use. This implementation may improve the operator's ability to store data but also compromise safety and increase the time required for the task. There are many additional concerns in the design of field computing that are not applicable to desktop systems. Field computing designs often need to address issues such as control through limited user interaction, sensing of the environment, data communication, power, and ruggedness. The user-centred design approach can ensure appropriate use of computing in the field by using the experience of the field personnel to focus on the critical aspects of operations.

The key to the successful development of field computing solutions is to focus on the information processing needs and field location of operations. User-centred design begins with extensive interviews with field personnel and visits to field operations. These observations are compiled into a baseline scenario that identifies the current state of operations including the process and products of the operation and the difficulties posed by the field setting. This information is then combined with field personnel "wish lists" to develop a visionary scenario of idealised field operations. A technology survey produces a list of potential system components. The developers use these components to design alternatives that meet at least the requirements of the baseline scenario and as much of the visionary scenario as possible. A successful field support solution requires: (1) a hardware system that is unobtrusive and designed based on the field inspector's tasks and mode of operation; and (2) a software system designed to support specific tasks by providing knowledgeable advice and context-sensitive forms of human-computer interaction. Communication with the field personnel is critical throughout the process, culminating in the testing, feedback, and design iterations of the selected alternative. Three examples demonstrate the application of this process.

During the spring of 1998, students at Carnegie Mellon University worked with inspectors from the Pennsylvania Department of Transportation (PennDOT), District 11 Office to design and implement an aid for bridge inspectors to use when inspecting bridges. The purpose of the Mobile Inspeciton Assistant (MIA) is to reduce the amount of time inspectors spend on paperwork so that they can spend more time inspecting bridges. When bridge inspectors are in the field, they take a clipboard with inspection forms, previous reports, a photo album, and a collection of generic sketches. To locate information, inspectors have to flip through a number of pages of information on the clipboard. Based on observations such as this and conversations with bridge inspectors, a wearable, speech enabled computer system with a flat panel display was selected as the best solution. MIA provides several data input modalities for bridge inspectors: handwriting, speech, and virtual keyboard. When one modality fails or is not working well, bridge inspectors can always change to another modality that works better for them. MIA integrates commercially available off the shelf software with an application specific user interface. The advantage of using commercially available software is that the prototype development time was shortened. However, inconsistency between the tool interfaces may lead to a steeper learning curve and effect the productivity of the inspectors.

The first prototype of MIA was demonstrated to PennDOT District 11 inspectors and engineers in April 1998, four months after the project was started. MIA has seen frequent upgrades since then to provide additional functionality. Several rigorous full-scale field tests are planned for the spring of 1999. These tests will determine how well the MIA system performs under field conditions and usage.

During the summer of 1998, students at Carnegie Mellon University worked with the Chevron Corporation and Applied Hydraulic Systems (Houma, LA) to design and implement the Offshore Supply Crane Assisting Resource (OSCAR) aid for oil platform crane operators to use for sensing and visualising the operating environment during critical lifts. Potential aids for the crane operators must also withstand a number of environmental and occupational hazards. System components on the boat, cargo, and platform will be exposed to the worst of a marine environment including sun, salt, water, and temperature variation. Two basic project areas emerged: identifying and extracting the data from the scene and processing the data and displaying it as information. Additionally, each component had to be designed to permit self-contained power and flexible mounting options while protecting against the elements, explosion, and physical abuse.

The chosen system design used a sonar transducer to vertically locate the cargo relative to the boat deck. Once the computer in the crane cab receives the data, it must be processed into information that can be readily acted on by the operator. The current display offers a single view with the deck of the boat shown to rise up to meet the cargo. This was chosen over a moving cargo and stationary boat that might lull the operator into thinking the boat was fixed. Visibility concerns ranged from the size and colour of text and objects to the type of display hardware. The user interface for the OSCAR system was kept deliberately simple; computer start-up is the only necessary interaction. Problems should be resolvable with the replacement of a component with a spare.

The OSCAR system has twice been tested on cranes using simulated cargo. Though neither of these tests incorporated the crucial element of the boat motion on real seas, they did allow the operators to offer valuable feedback.

January 1998 saw the start of a new project with General Dynamics Electric Boat (GDEB) Division. The project has developed several prototypes to address remote data access and communication needs at the boat assembly site. A large number of structural welds are performed while constructing a nuclear submarine. At GDEB, these welds are tracked using a mainframe-based system referred to as the Structural Weld Status System (SWSS). Tracking should be updated each time a weld progresses from one step to the next. In reality, SWSS updating is batched, thus causing several problems. If the records are updated as required, the supervisors spend a great deal of time away from the work site and in front of an SWSS terminal.

The SHIP project team at GDEB is currently building a "SHIP Desktop" from which supervisors will access and enter information about the jobs they are supervising. From this desktop, supervisors will be able to track their personnel, assign work tasks, authorise work, etc. The mobile computer being developed downloads pages from this desktop and displays them appropriately on the smaller screen of the mobile device. Wireless communication, a barcode reader, a Java ibutton, and a magnetic card reader have all been integrated into a prototype mobile device for this application.

Model-Based Diagnosis for the Monitoring Large Concrete Dams

Eliane PORTELA
Research Assistant
LNEC
Lisbon, Portugal

João BENTO
Associate Professor
IST-UTL
Lisbon, Portugal

João MORA RAMOS
Research Officer
LNEC
Lisbon, Portugal

Henrique SILVA
Research Officer
LNEC
Lisbon, Portugal

Summary

The aim of this paper is to present a knowledge based system to assist surveillance activities for large concrete dams. The system is based on the knowledge gathered through out the whole life of the dam - including design, construction, operation and mainly the data coming from the monitoring system and visual inspection.

Keywords: Structure, Dams, Safety, Monitoring, Deterioration, Expert Systems.

1. Introduction

The lifetime of large structures, such as dams, spans for decades. During the whole period of operation it must be guarantee that the essential safety requirements are completely fulfilled.

The safety of existing dams has been always a major concern of managers responsible for the safety of the communities. The increasing number and ageing of those structures lead the scientific community to look for new means to tackle the problem of dam safety control.

To assess the dam safety one must rely on a comprehensive set of facts and information which is available since the design and tends to increase rapidly through out the years. The safety of a dam may be established on the basis of a certain distance between the present dam behaviour and the "dam expected normal behaviour", which is supported by the pre-defined behaviour models. As the dam properties may change during the course of their life, the behaviour models must be revalidated from time to time.

Through the surveillance activity the changes in structural behaviour can be monitored and any anomalous situation should be identified by a thoroughly analysis. The main purpose of the present system is to give the support for an automatic identification of any anomalous situation, which may endanger the dam safety and propose corrective actions to avoid major incidents.

2. Abstract

One of the main goals of the present research is to elicit engineering reasoning processes out of the dam experts, so that a computer model of that expert reasoning could be developed.

The various means used for surveillance are measurements, visual inspections, in situ tests and laboratory tests. Measurements must characterise the structural response to the continuously changing environmental actions. These actions are mainly characterised through the monitoring of the following quantities: water level in the reservoir, water and air temperatures, facing or internal temperatures and uplift or pore pressures. The key quantities to define the structural response are displacements, strains, stresses, joint movements and seepage discharges. Visual inspections are also a reliable way of detecting both malfunctioning and deterioration. Regular examination by experienced personnel is an important element.

The effective control of dam safety requires that the measured data be interpreted in the shortest possible time following the readings. The resources offered present computing technology allows for this analysis to be carried out almost in real time.

Thus, the system used to support the analysis must be activated whenever an observed quantity falls outside the tolerance band. In the present system, this is done through a set of complex causal networks associating abnormal values or trends observed in the monitored quantities was established. The causal networks will point to a set o scenarios to be investigated. Three groups of scenarios were defined: general (scenarios related mainly with the loads, design and construction), scenarios related to the dam foundation and scenarios related to the dam body.

The correct identification of a scenario depends on the description of the appropriate symptoms. Part of the ability of the expert system to focus the search for possible scenarios on the ones that might afflict the structure results from an automated identification of which symptoms are of primary importance and which are of secondary importance for the diagnosis of an abnormal behaviour.

Primary symptoms are sure signs that a particular scenario has indeed taken or not taken place, and therefore present strong evidence for the diagnosis of a particular type of scenario. Secondary symptoms provide some information about possible scenarios and represent weaker evidence for this particular scenario. Secondary symptoms become relevant when a fine-tuning of the diagnosis is required or if insufficient information is initially available to make a diagnosis.

Once a scenario is identified by the system through association of symptoms, the expert system compares its findings with a knowledge source containing a series of problems with possible recommendations. If a match occurs, the expert system displays the result.

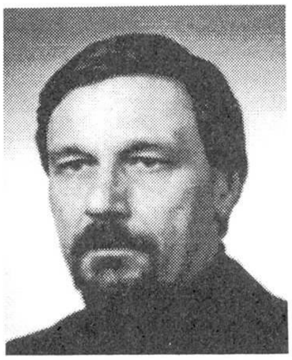
Recommendations may consist of remedial measures, methods leading to further investigation to confirm a diagnosis, a preventive measure, or even a mere statement that no action is required.

In Portugal there are about 100 large concrete dams of several types in operation The system under development is being applied to a specific case of a double curvature arch dam in Portugal during its period of operation. It attempts to monitor a number of specific data values and spot abnormal values or trends suggesting remedy measures to solve or mitigate foreseen problems.

The software used in monitoring systems should enable to perform safety assessment and evaluation of any scenario in development using both standard conventional programs and the ones based on artificial intelligence. An interface to the data acquisition systems should exist in order to assure a real time analysis. From a software packaging point of view, the whole system should be faced as a corporate memory system. The event of the widespread use of the Internet, namely through WWW technology, suggests that such corporate memory systems should become available and accessible via Intranet.

Ecobridge - Railway Bridge Management System for the Future

Jan BIEN
Dr Eng.
Wroclaw Univ. of Techn.
Wroclaw, Poland



Jan Bien, born 1950, received his civil engineering and Ph.D. degree from the Wroclaw University of Technology. Since 1993 has been responsibly for elaboration of the BMS for the Polish State Railways. Since 1997 has been involved in the UIC ECOBRIDGE Project.

Summary

The paper presents a preliminary conception of the ECOBRIDGE (ECOnomical BRIDGE) System which is elaborated by the Technical Subgroup Bridges (7J22) of the International Union of Railways (UIC). The main objective of the project is a cost-effective bridge management system which could be adapted by all interested railway organisations for international integration of the railway transportation systems in the 21st century.

Keywords: bridges; management systems; expert systems

1. Introduction

The ongoing development of the railway infrastructure, its greater complexity and the growing expectations of its users require a higher standard of the RBMS. In addition to the technological advancement of the bridge engineering another urgent need arises, namely making the systems intelligent by equipping them with the ability of learning, recognising, concluding, and even choosing and achieving goals. To meet the needs of many railway organisations the Technical Subgroup Bridges (7J22) of the International Union of Railways initiated in 1997 the ECOBRIDGE (ECOnomical BRIDGE) Project. The members of the group represent Banverket (Sweden), NS (Holland), PKP (Poland), Railtrack (United Kingdom), SBB (Switzerland) and SNCF (France).

Presented below a preliminary conception of the ECOBRIDGE System [7] is elaborated on the basis of 10-years experience of the Bridge Group of the Wroclaw University of Technology.

2. Objectives and scope of the project

The main objective of the UIC 7J22 project is elaboration of a system which could be adapted by all interested railway organisations for international integration of the railway transportation systems.

ECOBRIDGE should provide the tools for:

- assessment, monitoring and prediction of technical condition and serviceability of existing railway structures;
- assurance of traffic safety and service parameters required by the customers;
- optimal use of available maintenance funds;
- collection and processing of administrative, technical and economic data;
- knowledge representation in the system.

ECOBRIDGE tools should enable an individual treatment of each bridge structure on the basis of all data and knowledge collected in RBMS. Because of the international nature of the railway systems ECOBRIDGE should lead to a compatibility of all Railway Bridge Management Systems.

3. ECOBRIDGE architecture

Four main interrelated parts of the proposed ECOBRIDGE system can be distinguished:

- organisation of bridge management;
- scientific and technical basis of the system;
- knowledge-based computer system (Fig. 1);
- bridge staff (system users).

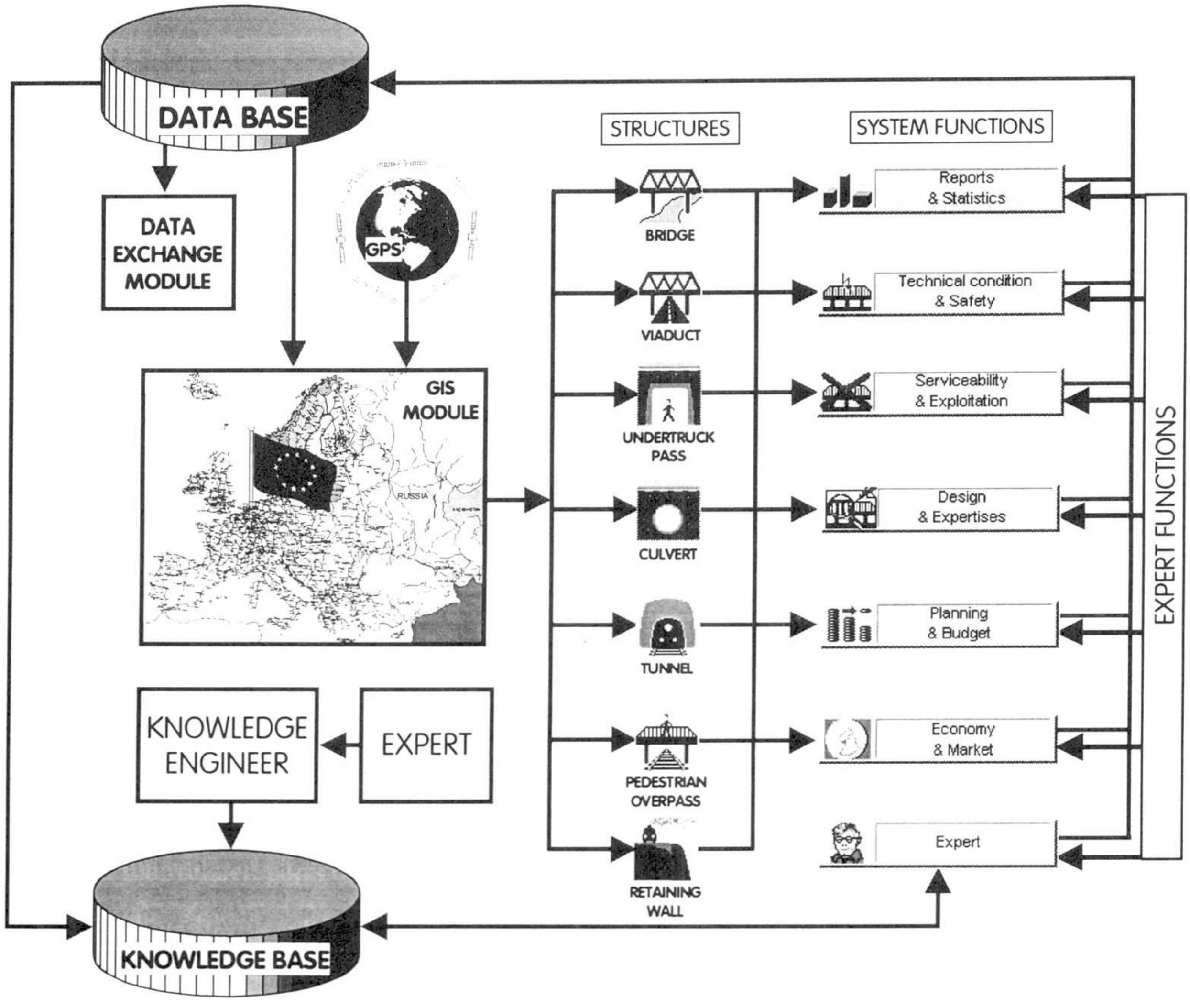


Fig. 1 Functional scheme of the computer part of the ECOBRIDGE System

4. Conclusions

Integration and unification of the bridge management systems are the most significant processes expected in the near future. Development of the systems should be stimulated by the international co-operation.

Quality Awareness in Education Practice

Charles J. VOS
Professor
Delft University of Technology
Delft; The Netherlands

Charles J Vos studied Civil Engineering in Delft (NL) and in Leeds (UK). He designed marine structures including GBS for oil production and developed many new IT systems within his work. He retired as Managing Director of Delta Marine Consultants and still teaches construction technology at Delft.

Keywords: Education, Quality assurance, Structural engineering, Computer aided learning.

What is new in education?

The objects to be touched and the objectives to be achieved by universities in the education of structural engineers are subject to growth and change. As a consequence a selection of subjects to be taught and a diversification based on future career profiles has to be made. This is not an easy task as objects for education reach from certain aspects from social systems to basic material characteristics. And the objective aims at the development of an attitude as a professional civilian as well as to an engineer who understands basic physical phenomena. Just in the middle of these extremes are the knowledge and certain abilities to design simple technical systems out of components being dealt with in codes and rules. Although this is the area of certification in professional practice, real quality is only added by basic understanding and a certain attitude towards a wider scope.

How to select from more for teaching?

A first selection can be made by considering three categories of careers when planning an education system. First, the non structural engineer, like traffic engineers and sanitary engineers, who will delegate structural engineering to others. Second the structural designer, trained for technical responsibility and engineering management and third, the specialist to work in research or for dealing with specific detailed problems of structures.

The next point for selection is the awareness of strength and weaknesses of present engineers as established in several studies, like the one referred to, named: 'The profile of the structural engineer in the nineties', issued in The Netherlands in 1989. Use of mathematical models and capabilities for analysis is considered as good, but the ability to select and interpret information, engineering judgment and knowledge and abilities in design methodology, are considered as a threatening weakness.

The paper explains by an example the relative value of technology embedded in codes. It refers to a Swiss experiment where 32 designers had to detail the same structure with the same code, which resulted in a wide range of solutions. This supports, that knowledge of codes should only be instructed in order to train students by executing cases in which code-checking forms part of the process of course.

A last point of attention when selecting for a curriculum are the secondary mechanisms in certain subjects that develop structural feeling. Sketching classic structures and analyzing structures by influence lines or hardy Cross Method did contribute to spatial consciousness and imagination of force distribution through structures. These secondary teaching effects are often lost because the primary cognitive meaning of these exercises is abandoned because it got out of date.

Educational experiments

An experiment in Delft is described where students were asked to adopt the principles of Quality Assurance in a case study. It was hard in the beginning, as the QA attitude of self control is completely different from classic teaching, where work is always corrected and approved by the teacher. The results improved in later years by specific teaching.
An other experiment describes the use of an intelligent CAD system for a case where students design a simple reinforced concrete building. The program has two levels of code checking. In first instance the sizes of concrete members selected by the students for beams, columns and slabs are checked against the Dutch code for under-reinforcement, over-reinforcement and potential economy. In a second check, the reinforcement as detailed and put into the system is checked against the Dutch code and commented.
This system is now in use for 9 years and over a 1200 students went through. It shows that IT systems can be used for a simple quality check in education, without substantial interference of staff. Some new problems are however introduced, like a trial and error approach towards the design and the hard yes or no judgment of the computer system. Efforts to extend the system internationally based on EURO-Codes failed because of the lack of interest in the university world being dominated by research and not by tools for productivity increase. For the same reason it was not possible to develop and implement a module to perform parameterstudies in the program for optimizing sizes of concrete members based on costs.

Research being carried out in Delft on different computer aided learning systems concludes that development of CAL-systems is rather difficult. It involves a level of teamwork and inter-discipline interaction as very unusual in academic circles. Apart from that thorough preparation and evaluation of implementation has to be performed in order to get a self learning system in an area where hardly any experience exists. Because of the high costs an economic evaluation of these systems has to be performed right from the beginning, as idealism and ambition as required for successful traditional education are not sufficient.

Conclusions

Conscious selection of objects and objectives in education of structural engineers is required and should be based on a future differentiation in career, on actual observed weaknesses, on the relative importance of factual knowledge and on implicit and explicit course contributions towards the development of structural feeling.
An audit on the quality of education in structural engineering could use these issues as a guideline.
CAE systems being used today are not at all integrated in overall design systems. Many things have to be learned about processes, the role of information and human action. This should reflect in education schemes.
It is hard to predict what structural engineering students should actually be taught in detail. It can however be certain that the complex process of teaching engineering judgment based on reference and the analytical approach of teaching to go through rational processes have both to be practiced.
The quality of education in structural design needs more attention and international collaboration.

References

A list of 11 references supports and completes what has been stated in the paper.

An Integrated Steel Design System Developed for Educational Purposes

Ricardo H. PEIXOTO
Civil Eng.
PUC-RIO
Rio de Janeiro, RJ, Brazil

Luiz F. C. R. MARTHA
Civil Eng.
PUC-RIO
Rio de Janeiro, RJ, Brazil

Pedro C. G. da S. VELLASCO
Structural Eng.
State University of Rio de Janeiro
Rio de Janeiro, RJ, Brazil

Sebastião A. L. de ANDRADE
Civil Eng.
PUC-RIO / State University of Rio de Janeiro
Rio de Janeiro, RJ, Brazil

Summary

The main goal of this paper is to present an educational software for an integrated analysis and design of steel structures. The system provides structural engineering students and designers with a graphical tool to speed up the assessment of various structural systems. The motivation created with this fast and user-friendly design process improves the students ability to obtain more suitable structural solutions. The member structural strength design checks are performed according to ultimate and serviceability limit states necessary to insure an adequate structural safety. The program displays, in an suitable graphical way, all the members designed together with their strength design ratios. The flexibility of the system enable users to change on the fly the suggested steel sections according to fabrication needs or any other constraints.

Keywords: Structural Design, Automated Design of Steel Structures, Interactive Design of Structures, Structural Engineering Education.

Abstract

Structural steel design programs are very powerful tools not only for the daily use of structural engineers, but also to help undergraduate and graduate students to learn and understand the structural behaviour. Unfortunately, these programs are very expensive and, in the great majority of cases, not suitable for an efficient educational use.

Students in regular courses spend much time exercising theoretical aspects of structural behaviour without exploring concurrent issues such as connection rigidity, sideway displacements, deflections; member resistance, fabrication and erection costs, fire resistance and others.

Regretfully, this design knowledge often will be acquired only after some years of experience. On the other hand, the fast development of computational resources and graphical interfaces allows a more active participation of users in the steel structures design process which provided the major motivation for this work. The idea is to develop a teaching tool to increase the understanding of the global structural behaviour and a well as providing a controlled design procedure.

This paper also presents a brief overview of the portal frame design process. The sway frame design methods were summarised and included: a linear first order analysis, an approximated P-Delta method and a second order analysis. The complete structural design of a non sway system is proposed with the aid of the developed software. This method can detect, by means of a fast structure reanalysis, if the structure has any potentially underdesigned members.

The software FTOOL (Bidimensional Portal Frame Structural Analysis), developed at PUC/RIO was further expanded to include the steel structure design. Limits states design philosophy was implemented in the program, taking into account serviceability and resistance requirements used in the Canadian Code ,CAN/CSA-S16.1-94, [1].

A brief description of the program FTOOL in found elsewhere [2], [3]. The program has been used for teaching undergraduate students and was recently converted to the Windows environment. Extra modules as well as modification in others programs procedures had to be implemented in FTOOL to make the steel structure design user-friendly. A steel section data bank with a comprehensive set of information on standardised profiles was created to facilitate the structure input phase. A graphical interface based on IUP/LED, [4], a portable system user interface and CD, [5], Canvas Draw developed at the TECGRAF/PUC/RIO form the basis for input and output visualisation. The program developed is fully portable and can run on IBM-PC environments, or X-Windows based systems. The main modifications performed in data structure of the FTOOL program, were implemented to include geometric, material and design properties, required for the structural design [6].

The graphic interface used in the program FTOOL was created with the objective of assisting the user's needs and simplifying, as much possible, the data input generation. The menus and submenus implemented consisted in: pre-processing, post-processing and structural design.
The structural design checks for a given member included: cross section capacity, overall member capacity, lateral torsional capacity, shear capacity, vertical and lateral displacements assessment.

The full interaction of the implemented module of: pre-processing, post-processing, structural analysis and structural design is achieved through an user-friendly interface. A flexible environment is created enabling designers and students to use the results obtained in one module as input requirement for others. This strategy induces a step by step procedure very efficient for teaching structural design and analysis. The possibility of using different structural sections can also improve the students learning ability on structural analysis and steel structures behaviour.

The program FTOOL serves as an useful tool to speed up the design process. A cost reduction investigation can be performed for a given structure through the design of alternative structural solutions. The program also enables the selection of a roll of sections according to fabrication or any other design requirements. This feature can significantly reduce the structure's fabrication and erection

References

[1] Canadian Standards Association, *Limit States Design of Steel Structures*, National Standard of Canada, Rexdale, Ontario, 1994.

[2] Grupo de Tecnologia em Computação Gráfica - TecGraf, *FOOL User Manual*, version 1.0, PUC-Rio, Rio de Janeiro, 1994. (in portuguese)

[3] Cavalcanti, P.R., *Criação e Manutenção de Subdivisões do Espaço, Ph.D. Thesis*, Computer Science Department, PUC-Rio, 1992. (in portuguese)

[4] Grupo de Tecnologia em Computação Gráfica - TecGraf, *IUP/LED – Sistema Portátil de Interface com o Usuário, Reference Manual*, Rio de Janeiro, 1996. (in portuguese)

[5] Grupo de Tecnologia em Computação Gráfica - TecGraf, *CD – Canvas Draw – A 2D Graphics Library* , *Thecnical report*, PUC-Rio, Rio de Janeiro, 1997. (in portuguese)

[6] Peixoto, R.H, *Um Sistema Integrado para Análise e Projeto de Estruturas de Aço, M.Sc. Dissertation*, PUC-Rio, Rio de Janeiro, 1999. (in portuguese)

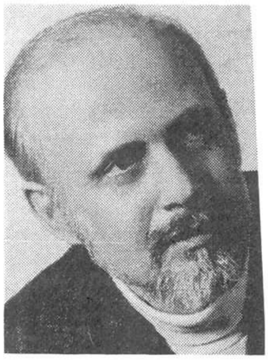
Learning Engineering from Breakdown Cases

Ziga TURK
Assoc.Prof.
Univ. of Ljubljana,
Ljubljana , Slovenia

Born 1962; received degrees in structural engineering and computer science in Ljubljana; teaches CAD and engineering drawing; works on information technology in construction.

Matej FISCHINGER
Professor
Univ. of Ljubljana,
Ljubljana, Slovenia

Born 1954; professor of earthquake engineering and reinforced concrete structures. His research is concerned with inelastic design procedures in earthquake resistant design.



Summary:

Engineering decision making processes are not always rational. Intuition, feeling, common sense and other forms of pre-rational mechanisms are used as well. They are based on knowledge accumulated while "being-in-the-world", and particularly during breakdowns. Studies of engineering disciplines are predominantly theoretical and students have few opportunities to learn from experiences or breakdowns. It is proposed that information technology, particularly virtual reality and multimedia, would allow them to share the experience of those few that had such opportunities. An electronic publication is presented, that uses breakdown cases to convey structural engineering knowledge of earthquake resistant design of reinforced concrete structures. It based on more than 500 commented and classified digitised images. The system proved efficient and was found to complement the related theoretical knowledge.

Keywords: education, earthquake engineering, multimedia, case-based iearning, breakdown

Most of engineer's work is founded on solid mathematical and mechanical foundations, however, particularly during conceptual design process, more primal decision making mechanisms such as "feeling", intuition, insight and common sense also take place. They are not learned as much in school as in the everyday life - as Martin Heidegger would have put it - while "being in the world". Buildings like the one in Fig. 1 (right) are not designed because of experiences such as in Fig. 1(left). But buildings such as the one in Fig. 2 *are* designed and can fail (as shown in Fig.3) but no "feeling" speaks against them.

Experienced engineers are gaining the "feeling" during their whole career. Psychologists and philosophers claim that learning is most efficient when things go wrong - while real life problems are being solved. Teaching of young engineers should reflect that. Studying and experiencing failures provides valuable lessons in general.

We propose (1) that some engineering topics can be efficiently learned from breakdowns, that (2) such learning also contributes to the pre-rational knowledge, feeling, intuition and that (3) hypermedia can be used to implement it. We prove the hypotheses with a system to teach earthquake engineering - EASY.

Earthquake engineering is a particular well-suited topic to implement these concepts. Fortunately for the general population, but unfortunately for the structural engineers, earthquakes happen very rarely. Additionally, the effects that the earthquakes have on buildings are extremely difficult to model in a laboratory. It is therefore very important to be able to share the "in-the-world" experience of those that have seen what earthquakes do to engineering built structures.

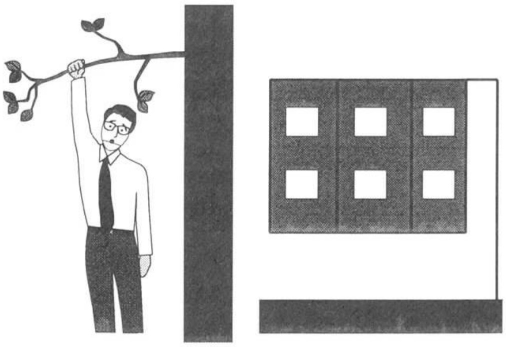


Figure 1: Not applying common sense experience (left) to engineering design(right).

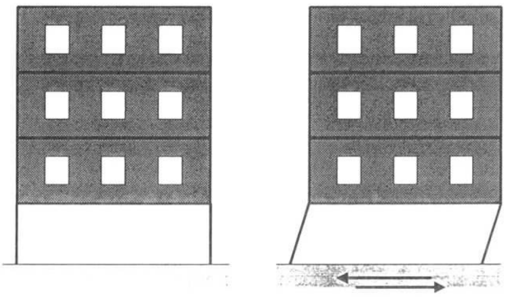


Figure 2: Typical soft storey structure.

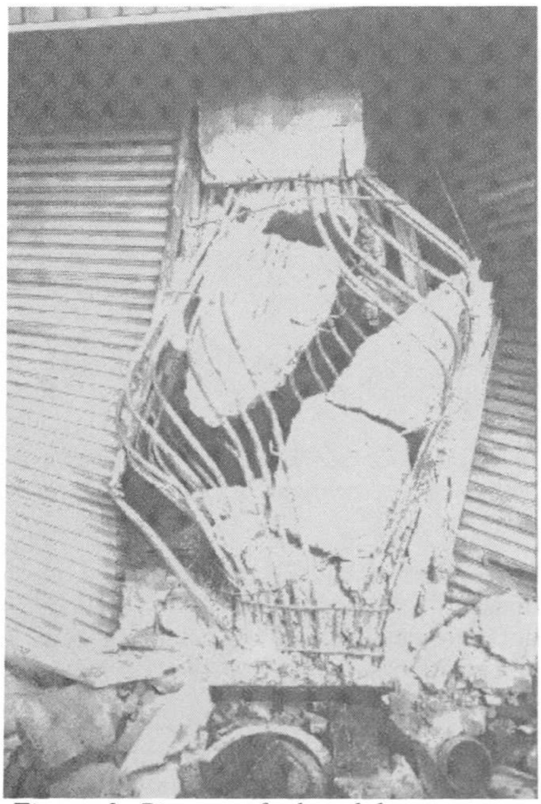


Figure 3: Picture of a breakdown.

A system has been created that structures a lot of the knowledge related to earthquake engineering around the failures and breakdowns. It uses hypermedia to show the breakdown realistically, triggers interest and the natural curiosity and offers hyperlinks that lead the exploratory mind of a student to informal and formal knowledge about earthquake safe design. It is available on the Web at

http://www.ikpir.fagg.uni-lj.si/easy/.

The system implements the idea of breakdown oriented learning and models the learning process into four steps:

Breakdown: The breakdown is shown as a color image of a collapsed structure or detail (as in Fig. 3). It captures student's attention and triggers the "will to meaning". Hundreds of pictures are available that show collapsed structures and details of structural elements.
Rationalization: A lot of structured information about a slide is given, both structured in various classifications, as well as in the form of unstructured comments. Explanations for the failure of this particular building or element are given.
Generalization: Failures have been classified into nearly 20 failure types. In depth explanations are provided on how and why such a failure type occurs. Hyperlinks lead to other slides that show the same type of failure or are similar to the examined one by one of the criteria. By following them, students gain a more general view on the topics and can explore the more general views on the problems of earthquake resistant design.
Conceptualization: Hyperlinks to textbooks and into the related building code are provided. More formal, higher level models related to the original breakdown are shown. Formal knowledge from the domain of structural dynamics as well as recipes from building codes are given.

Ever since visiting the earthquake sites and taking photographs it has been intuitively that structuring engineering knowledge around breakdown cases could be a useful and attractive approach. It was well accepted by students and educators. This paper, post-festum, provides the rationalisation: why it works. And hopefully eases the development of similarly conceived systems for example related to the fire safety, general structural safety etc.

Active Integration Concepts Based on a Communication Standard

Ulrich SCHNEIDER
Computer Scientist,
Bauhaus-University
Weimar, Germany

Ulrich Schneider, born 1966, received his computer science degree at Bauhaus-University Weimar. He is currently finishing his Ph.D. in Computer Aided Engineering at the same institution.

Karl BEUCKE
Professor
Bauhaus-University
Weimar, Germany

Karl Beucke, born 1951, received civil engineering degrees from Ruhr-University Bochum, North Carolina State University and University of California Berkeley. He is now a professor of Computer Aided Engineering.

Summary

Many civil engineering tasks are supported by specific software systems for a specific application. Integration of engineering information is often approached as an exchange of digital data between separate application software systems via standardised data exchange definitions.

Current approaches assume a "passive" involvement of the engineering user. The user basically asks for a complete set of digital information to be transferred into a standardised "data exchange format" which then can be used to be read by another engineering application software system.

In this paper a method is proposed which much more resembles traditional ways of utilizing engineering information generated in separate processes. Functionality is provided for "actively" transferring specific aspects of engineering information defined in the context of a specific application into another context of a separate application. This is achieved on the basis of a standardized communication technology. This process can furthermore be enhanced to support a revision control of engineering information modified in one context and utilized in a separate one.

Keywords: application integration, data exchange, semantic object model, information integration, active integration

Abstract

Engineering processes are characterized by many separate solution processes which are carried out in parallel by different engineering teams. Solutions are communicated via technical documents which are used to transport information between these teams.

Conventionally, an engineering user of technical documents interprets visually information on these documents and selectively extracts information needed for reuse of this information or of specific aspects of this information in producing or updating another document. Thus, the engineering user "actively" interprets the semantic meaning of information on a document and again actively selects the desired information for use in the context of another document.

Standard methods for data exchange do not support this process but rather transfer all information indiscriminately into a predefined format. This implies that data within a source document needs to be converted into a "standardized exchange format" and based on this format new data will be created in a target document.

Securing consistency of information is virtually not supported at all in either one of these two

approaches. In the conventional process the engineering user is totally responsible for comparing documents and for deciding on necessary actions to be taken. Standard data exchange methods technically allow for strategies with that respect but there is very little work done to solve this problem.

When comparing advantages and disadvantages between the two approaches it can generally be concluded that the conventional approach is very flexible, well established in the design process and better suited for continuous considerations of minor revisions. However, there is a lot of effort associated with reentering information which was already entered in the context of a separate task. This, of course, leads to a lot of redundant information which needs to be maintained. Information integration is a difficult and time consuming task. Data exchange methods work well for generating a new technical document. Initial information can be transferred quickly and safely. However, it allows for very little flexibility and strategies for revision management and for handling redundant information are generally not provided.

The key idea of the approach presented in this paper is to combine conventional approaches of information integration for technical documents with data exchange methods. The active involvement of an engineering user in the process of information integration requires enhanced methods of data exchange. The assumption is made that two application software systems are used to generate and maintain two separate sets of information (engineering models). These two systems may be used concurrently by a single engineering user. Both contain information which is redundant as a whole or in certain aspects, i.e. some information is derived from one system for use in another. The user running both systems can "actively" control what information is needed from the source system and transfer associated data into a target system. This process is documented for tracking dependencies between information in separate models. Thus, two major tasks can be identified: transferring data between separate applications and securing consistency of information transferred.

In this approach, the necessity to standardize the semantic object model of objects that are part of the integration process is not given anymore. The reason for this fact is the need for the user to interpret actively any data that is part of the integration process. The prerequisite for this approach is the requirement that all applications make its object description publicly available and the integration software supports creating new objects dynamically, i.e. objects description and status.

The utilization of a standardized communication relating to the exchange of objects, the manipulation of selected objects, and the notification mechanism needed for securing consistency for the process of information integration of engineering documents offers new prospects. It can be shown that it allows an engineering user to be actively included in the process of information integration, thus combining the advantages of two approaches currently used for these purposes.

The result is the definition of an integration software which relies on these technological concepts. The integration software must be customized for use in a specific configuration of selected applications on the basis of the correspondent object models. Once, this definition has been made – defining a specific configuration – it can be used repetitively for the purposes of information integration between a specified configuration of engineering applications. This would offer prospects for a real advancement in the process of integration information of engineering documents.

Extending Active Control to Build Intelligent Structures

Ian F.C. SMITH
Professor
EPFL - Federal Institute of Technology
Lausanne, Switzerland

Kristina SHEA
Lecturer
Cambridge University
Cambridge, UK

Summary

Intelligent structures react to changes in their environment (loads, movements, etc.) through *i)* measurement of structural behaviour, *ii)* evaluation using knowledge bases, *iii)* use of computational control to modify actively structural characteristics and *iv)* use of past events to improve structural performance. A computational framework based on intelligent control methodology is presented that combines reasoning from explicit knowledge, search, and learning to illustrate capabilities of intelligently controlled structures. Using this framework, a computational system and its application to tensegrity structures are under development. Such computational control systems are stimulating the design and construction of innovative structures, thereby extending design possibilities for structural engineers.

Keywords: Active control, intelligent structures, case-based reasoning, simulated annealing, tensegrity structures

1. Introduction

The potential for intelligent structures stems from a combination of advances in structural engineering, control engineering and artificial intelligence research. For structures that are governed by safety criteria, most active control systems will not be reliable enough over service lives without expensive system maintenance. Such extra costs are difficult to justify economically. When dominant design criteria do not involve catastrophic collapse or loss of life, active control is most practical. Active control of structures provides a means of continuously controlling performance of complex structural systems to ensure good performance in changing and uncertain environments. Use of artificial intelligence (AI) methodology has the potential to enhance the benefits of structural control. This paper begins with a discussion of potential applications and refines the definition of intelligent structures given in the summary. A computational framework is outlined in Section 3 and this has been applied to tensegrity structures in Section 4. This application employs a unique control system (Section 5) that is an instantiation of the computational framework.

2. Intelligent structures

The term "intelligent structures" has been used to describe structural engineering technologies ranging from structures with embedded active materials to structures with artificial neural network controllers. This paper introduces a refinement of the definition of intelligent structures in order to provide a focus on long-term performance-based control of civil structures. Intelligent structures have two attributes: at least one active feature, and a computational control system that performs functions such as : adaptation of structural geometry to improve performance; control objectives that arise from multiple, changing performance goals; autonomous and continuous control of multiple, coupled structural subsystems; reasoning from explicit and modifiable domain knowledge; improvement of structural performance over time (learning and planning).

3. Computational Framework

Details of the computational control methods are shown in Figure 1. Many combinations of reasoning, search and learning methods can be used within this framework.

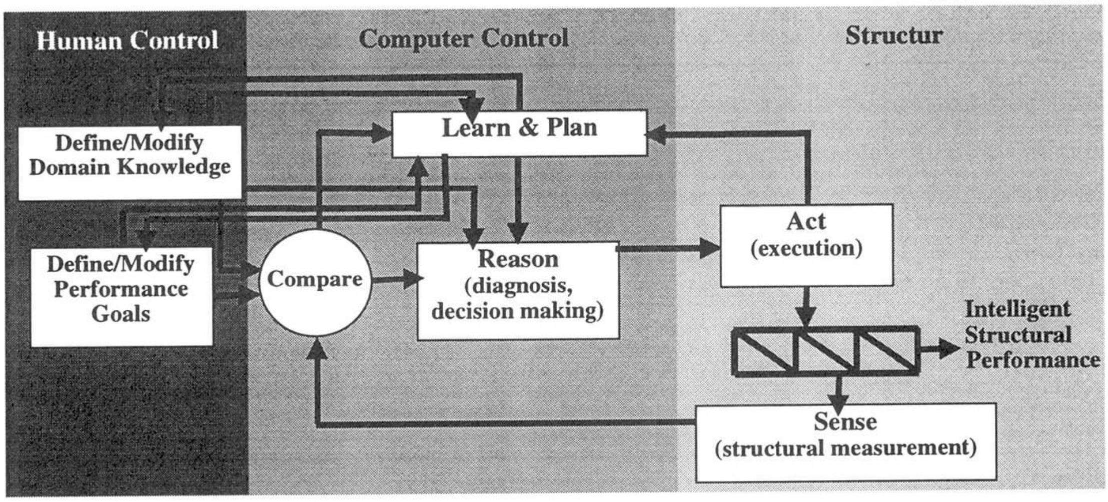


Fig. 1 Framework for intelligent computational control of complex structures.

4. Application to Tensegrity Structures

Tensegrity (tensile-integrity) structures are lightweight, reusable structures. Since tensegrity structures are sensitive to asymmetric loads and small changes in external loading, active control helps make them suitable for practical use. A system developed from the framework presented in Figure 1 is intended to control tensegrity roof structures such as those employed for exhibition at the Expo.01 in Switzerland in 2001. The design consists of coupled active features that require continuous control in order to maintain and improve system performance. A roof system is comprised of tensegrity (tensile-integrity) modules each of which consists of a self-stressing system of compression struts and tensile wires where the stress distribution and shape of the module is controlled by telescoping struts. The control problem is then to determine the lengths of active struts that best distribute the stress in the structural system in a changing environment while keeping the roof fabric in tension.

5. Computational Control System

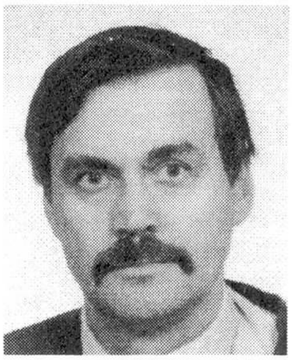
For the tensegrity system described above, the initial behavioural objectives are shape control to maintain fabric tension and stress control to keep wires from going slack. Given a loading condition and corresponding structural deformations, the computational control system determines a set of movements of the active struts that will return the structure as close as possible to the initial shape. To achieve these structural control goals the current computational control system is comprised of three modules: (1) state evaluation, (2) simulated annealing search, and (3) case-based reasoning. Simulated annealing performs a global search of the combinatorial space of possible movements to produce control solutions. Since simulated annealing is a lengthy iterative process, a case-base of previous solutions acts as a means for speeding up reasoning and for enhancing solution quality through knowledge about past successes.

6. Conclusions

When serviceability requirements are important design criteria, continuous active control becomes justifiable. Intelligent structures are capable of interacting with complex environments and improving performance with time. Structural control systems which use explicit knowledge representation, search and learning, will create new possibilities for innovative, active structures.[1]

Computer-Aided Quality Monitoring of Bridge Construction

Torsten LUNABBA
Licentiate of Technology
Road Administration Finnra
Helsinki, Finland



Torsten Lunabba, born 1946, received his civil engineering degree from Helsinki University of Technology 1972 and his Licentiate degree 1985. After working for a consultant and the Helsinki Public Works Office he has been with Finnra since 1990.

Summary

This paper describes the Computer-Aided Quality Assurance system used in Finland for bridge construction. An exhaustive list of Quality Requirements is recorded by the consultant in a data file, which is submitted to the construction site. The contractor makes his checks and documentation in the same data file.

1. Introduction

Site Control and Inspection by the client supervisors have gradually been replaced by the companies' self-control and by applying of Quality Assurance Systems. This has been a necessity, since a lot of the production takes place in subcontractor's workshops and their time schedule is so tight, that no client can provide enough supervisors to implement a comprehensive control.

2. Quality Requirements

According to contracting praxis in Finland, the client is not providing the contractor with any guidelines how to implement his works. Instead, the Quality Requirements are precisely and in detail defined particularly for the end result of different structural components. Most Quality Requirements to be applied are found in the General Quality Requirement for Bridge Construction handbooks published by the Finnish National Road Administration [1]. The consultant shall define Quality Requirements for each work step of a bridge project. This rather long list is created easily by computer using the database of the software, which include the most common Requirements as well as National Codes for different construction materials. Requirements for a new bridge project also may be copied from that general database or from a previous project.

The consultant does not need to produce any text such as guidelines, but instead he shall define the Requirements in charts, which are easy to use for Quality verifications. Typical and commonly used Requirements for a foundation pit are presented in Table 1. The digits 1, 2 or 3 indicate the type of the Requirement. The Requirement types are as follows:

Type 1. This bridge specific Requirement is set by the consultant. In this case the consultant has decided to have the water to be pumped from the pit so that the water level shall be 0..0.5 m below the bottom level. This is set to avoid hydraulic collapse in case the water is lowered too much. On other hand the pit shall also be dry, which is set by putting an upper bound on the water level.

Type 2. This is a standard Requirement, which is found in the General Quality Requirements of the Finnish National Road Administration and references thereto. Type 2 Requirements are in fact the dominating ones. The type 2 Requirements do not need to be printed out for Tendering and not necessary later either. The list of Requirements shall be sent to the site in a file on a diskette or by e-mail and after that handled only by the computer.

Type 3. This is a non-obligatory Requirement recommended by the consultant. The slope of the pit is here set to 45 degrees (1:1), but the contractor may also excavate in a strutted pit or apply any other acceptable working method.

7110 Excavation and blasting of the foundation pit
7111 Excavation without strutting

Code	Work Specification	Type	Required	Lower limit	Upper limit	Unit
100	Level of ground water measured from the bottom level	1		-500	-100	mm
200	Horizontal location of bottom measured from the theoretical level	2		-300	50	mm
300	Base levelness measured from the lowest point	2		0	150	mm
400	Slope of the pit	3			45	degrees

Table 1. Quality Requirements for excavation without strutting.

3. Work Steps

The Quality Requirement items shall be defined for each Work Step, which describe the implementation of works and also constitute the structure for the Quality Requirement file and the Proof of Acceptability documentation. These are typically:

BRIDGE CONSTRUCTION (General features)
EXCAVATION AND BLASTING OF THE FOUNDATION PIT
EARTHWORKS, FILLING, PILING WORK
FOUNDATION
ABUTMENTS AND PIERS
SUPERSTRUCTURE
DECK SURFACE STRUCTURES
EQUIPMENT AND ACCESSORIES

The Work Steps are divided into subdivisions, and those are for example for a prestressed superstructure as follows:

SUPERSTRUCTURES
- Scaffolding and formwork
- Reinforcing
- Concrete casting
- Prestressing
- Finished product

4. Quality Assurance

The proof of acceptability shall also be done in a straightforward manner. A computer system is used to store and sort out such essential data such as deviations. The data file of Quality Requirements for a particular bridge gathered by the consultant is a natural base for site Quality Documentation. When all measurement and check data is logged into the data block of each individual Quality Requirement, acceptability is easily and sufficiently proved. This will also facilitate the systematic analysis of the entire work performance.

References

[1] *General Quality Requirements for Bridge Construction SYL parts 1 – 7.* Finnish National Road Administration, Helsinki 1996. 600 pp.

The Hungarian Bridge Management System

Istvan MOLNAR
M.Sc. Civil Engineer
State Company for Public
Szekesfehervar, Hungary

Laszlo LUBLOY
Professor
Szechenyi Istvan College
Gyor, Hungary

Andras BAKO
Professor
Technical College of
Budapest, Hungary

Abstract

In the years past new period opened in Hungary not only in the politic, society and economy, but also in the bridge management. To support the development of the market economy and to improve the internal and international traffic the road directorate should make an effort to ensure the costs (with domestic and foreign resources), politicians should be convinced of the efficiency of bridge projects. In Hungary several elements of the bridge management have appeared in the past decades (e.g. bridge database, bridge inspection). This study summarizes the results and draws up the further steps.

The efficient management of the traffic infrastructure in any country can be performed exclusively by using a scientifically based up-to-date management system. The bridge maintenance, improvement and rehabilitation demands also in Hungary exceed the available financial sources. The Hungarian Transportation, Communication and Water Mangagement recognized this fact and has made efforts to implement and operate a Bridge Management System. Bridges are complex structures, the materials of bridges are very sensitive for environmental effects (e.g. air pollution, deicing systems). Bridges are the most dangerous parts of road network, according to growing of traffic (both number of vehicles and load axle). Simultaneously, failure of bridges cause a serious economical disadvantages for road users. Repairs or replacements need a lot of society expenditures. For the solve this complex technical-economical optimalization task (and the analysis of possible alternatives) more and more country apply Bridge Management Systems.

The basis of all kinds of maintenance and improvement work is the bridge registration and inspection. The computer based bridge registration was introduced in Hungary in 1965. In the 1980's the National Road Databank was established, which put the data of the bridges on record. The other base of the bridge management is the bridge inspection, which should be done by a bridge engineer on every bridges at least once a year according to the Hungarian rules since 1956.

The main decisions, steps in the introducement of the Hungarian BMS were made in the 1990's, and there were 2 programmes:

- a Middle-Term Bridge Maintenance and Improvement Program for the Years 1992-2000;
- implementation of the PONTIS Bridge Management System (network optimalization system for bridge improvements and maintenance, Pontis is an outgrowth of Federal Highway Administration Demonstration Project 71, USA).

The main aims of the Middle-Term Bridge Maintenance and Improvement Program for the Years 1992-2000 were the followings:

- the state characterization must be unified and must be as objective as possible;
- in spite of limited funds the program has to give exact results for the decision-makers.

The bridge network was inspected in detail (condition state, needed action with quantity) referred to 1272 bridges.

The data about the bridges were analysed as follows:
- condition-analysis and expense analysis of the bridges;
- changable parameter ranking of the bridge to maintain.

During the processing of the condition analysis we had the following experiences: we can say - taking into consideration the comparison of the condition-qualification and the age of the bridge - that according to the operating policy of the last years, the deterioration of the surface and substructure is 40-50 years, the bridge deck and accessories are 20-25 years and the environment is 10-15 years, after passing the mentioned years it stagnates at the same level. The stagnation of the qualifying numbers certificates the right of the 'steady state' of the PONTIS.

The Hungarian Bridge Management Task Group dealing with Hungarian BMS suggested in 1994 to introduce the American PONTIS-system (developed by the Federal Highway Administration). Utilizing the flexibility of the original system we developed a bridge element system which depends on structural function and material and is guided by the Hungarian features. We determined the definitions of the elements' condition states, the feasible actions and the costs of each actions. We named the system converted into the Hungarian features - as distinction from the American version - PONTIS-H.

According to the first runs of the program we can state during how long time and in case of which maintanance cost the maintanance backlog grows, stagnates, reduces or disappears (Figure 1.).

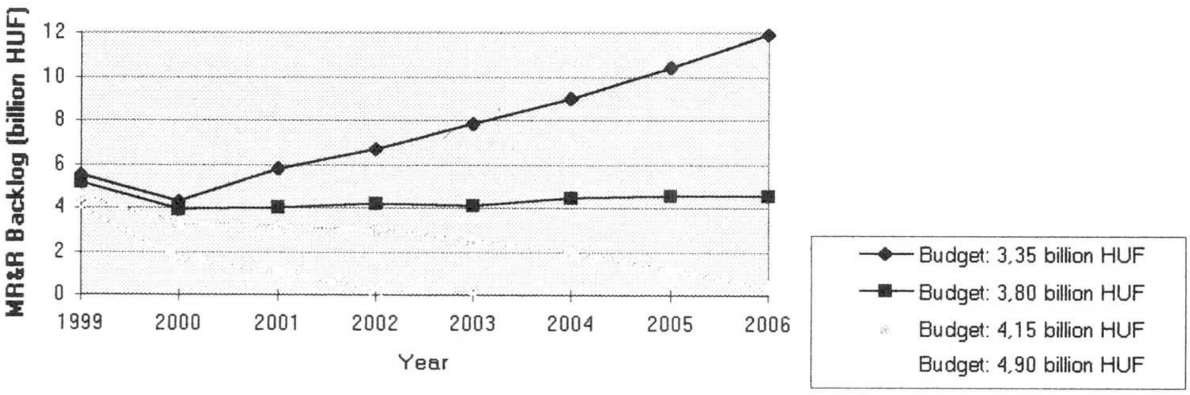


Figure 1. MR&R Backlog at various annual budgets.

We tested the established system, then we made the first version of the condition state and quantity recording system final in accordance with PONTIS-H by analysing of the summarized experiences. PONTIS makes also part results in that certain bridge owners are interested: for example what is the optimal condition state like in case of a bridge element, what kind of character the difference of the current condition state from that has. In 1997 condition state examinations started in accordance with PONTIS-H. By the end of 1998 correct PONTIS database was at disposal about 36,7% of the stock.

Development of PONTIS-H has run in two ways. The Project Oriented BMS based on the PONTIS-H. Using the results of the optimalization modul on network level the project oriented Bridge Management System develops it in the way of project level. Our aims were during the mathemathical developing of PONTIS optimalization method: optimalization of all bridge elements at the same time; handle of the interrelated elements together; network-level optimalization of the so-called span types of bridge containing the same bridge elements.

Management System for a Highway in Brazil

Margarida do NASCIMENTO
Civil Engineer
MCN Engenharia
Rio de Janeiro, Brazil

Clara FERRAZ
Civil Engineer
Concessionary Rio-Teresópolis
Rio de Janeiro, Brazil

Pedro LANCASTRE
Marketing Manager
Concessionary Rio-Teresópolis
Rio de Janeiro, Brazil

Elisio LINCOLN
President
Concessionary Rio-Teresópolis
Rio de Janeiro, Brazil

Carlos Henrique P. SIQUEIRA
Technical Director
MCN Engenharia
Rio de Janeiro, Brazil

Managing the physical structures of special works of art has been widely discussed recently among Brazilian specialists, mainly as result of the increasing number of concessions for federal and state highway administrations.

This fact, allied to new political-economic-social parameters, has been leading both government agencies and private companies to the development of efficient management methodologies and techniques for operational and engineering processes. On the other hand, their interest in such issues is nothing new among specialised engineers, and has long received special attention from those professionals dedicated to structure pathology, as well as from consultants and designers of special structures named in Brazil "special works of arts".

Based on the wide experience of its technical team, MCN Engenharia has developed a computerised system to monitor and manage the bridges, viaducts and pedestrian bridges located at BR-116 using information on constructions, identifying abnormalities through visual and equipment-assisted inspections, creating repair procedures for any type of abnormality detected, recording photographs and drafts on video, creating budgets and service timeframes, generating reports on pathologies and treatments, establishing rehabilitation priorities etc.

Process Definition in the Management of "Special works of art"

The main objective of any entity responsible for maintaining a road system is to "guarantee a satisfactory level of safety for both its users and the population under its influence, with adequate application of resources".

The standardisation of the processes related to road maintenance management aims at making sure that *"the infra-structural maintenance processes are being developed with methodologies that can provide standardised and almost instant responses."* Such responses can be obtained by implementing database systems that record and store all information instantly after their collection, guaranteeing the register and identification of all those in charge of maintenance. The system allows:

- prompt access to information;
- accomplishment within pre-established timeframes;
- continuous recycling of information;
- standardisation and continuous data exchange;
- selective access to information, according to user's needs;
- the verification of trends, regarding the evolution of each location surveyed.

Using decision-making and prioritisation techniques has become fundamental, and this requires the construction of a decision-making system. This system is expected to allocate properly all the resources available, observing the following criteria:

- What must be done?
- How must it be done?
- When must it be done?
- How much will it cost?
- Who will do it?

Or, more specifically:

- Which locations must be treated?
- How often?
- What is the best moment to perform repairs, carry out a treatment or improve it?
- How will such tasks be accomplished?

The importance of monitoring

When the wear presented by any existing structure does not receive timely treatment, it becomes an irreversible and natural process. One major characteristics to be observed closely in any structure is not the fact that it presents wear, since this is a natural process in all elements of a special work of art, but *how* this process starts and how long it takes to develop. There are two ways to treat wear. The first one is to develop studies that allow the examination of the types of deterioration processes installed. The second one is the fastest, most technically adequate and inexpensive way to eliminate wear when the structure already presents some deterioration.

Since wear processes are natural ones and can therefore be anticipated, the structures in the first situation will require interventions to relieve the installation of deterioration processes. On the other hand, other interventions are totally unexpected, since no previous studies or examinations have been performed on the structure. The two distinct situations lead to different strategies: preventive maintenance and corrective maintenance (repair).

Application of a management system - SIMGO
In order to increasingly reduce costs with unexpected repairs in special "works of art", it is essential that managers and users of the system can count on prompt information, which allows them to make decisions fast, based on a precise diagnosis. This is exactly the objective of the system.
It was developed aiming not only to provide information obtained during surveys and stored in databases, but also to plan the services and generate technical reports developed by specialised professionals, including the costs of operations and respective timetables.
The system is easy to use and allows greater flexibility when searching information. It runs on the Windows platform and requires no previous knowledge of other computer tools. It can also be used in a network environment, where several users can access information at the same time.
Maintenance – This term is used to define the actions performed in order to keep the structure under satisfactory operating conditions within the expected budget, usually by means of regular and planned interventions.

Structural Maintenance – Structure maintenance is a combination of all the technical and administrative actions taken to guarantee or reestablish the conditions required by any structure for satisfactory performance of its duties (British Standards 3811/84).

Preventive Maintenance – Preventive maintenance are all actions taken at regular intervals, based on two different criteria. The first one is contained in the project, which is concerned with keeping the best possible conditions of all materials and procedures for which the structure was designed. The basic assumption here is that maintenance is to be performed during the whole life of the structure. This way, a great deal of its behaviour can be previously known.

The second criterion is to base operations on the information obtained during inspections at random intervals. Usually, when such occasional surveys can identify problems, the structure has already been under use for a significant amount of time.

> Important Concepts in Preventive Maintenance: **Pre-defined criteria for projects, materials and implementation**; and **Pre-established periods for surveys and treatments.**

Corretive Maintenance – Corrective maintenance results from an unexpected intervention which used no criteria to follow up on the structure. It is usually performed after the surveys motivated by the identification of a problem.

Repairs – This term refers to unexpected interventions.

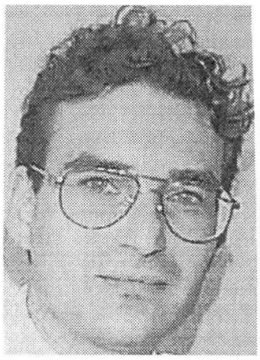
1. In order to cope with the natural wear presented by structures, it is necessary to develop a way to track their deterioration by means of regular inspections, realised in pre-established periods. This monitoring allows managers to identify the deterioration mechanisms acting on the structure, as well as their specific types and particular pace of progression.
2. Monitoring requires a study of the costs needed to implement regular inspections and define the treatments to be conducted.

A correct planning of inspections and interventions, as well as the consequent budgeting for their execution can result in significantly lower operating costs and structure use.

Monitoring the performance of a "special work of art" permanently allows the creation of important *preventive maintenance* criteria. That is why is important to implement a system using a tool like that it was used at BR-116/RJ.

Learning from the Damage History of Bridges – A Case Study

George RACUTANU
Licentiate of Technology
Swedish Nat. Road Adm.
Eskilstuna, Sweden



George Racutanu, born 1962, received his civil engineering degree in 1990 from the Royal Institute of Technology, Stockholm, Sweden.

In 1998, he obtained his licentiate of technology degree from the same institute.

Summary

The Swedish Road Administration has, at the present, a relatively intact and well-organised bridge archive system. Most of the former bridge inspections performed on the public road network after the nationalisation of the Swedish roads in 1944, are documented and stored in different archives throughout the country. The information from these inspections has been fed into a Microsoft Access database called BEA (Bridge Element Analysis), with the purpose to explore the possibility to determine the damage occurrence, damage growth and the real service life for bridge structural members.

In this case study it is examined, if certain information and factors like geographical location, traffic, and weather data at the time of casting, affect the service life of bridge structural members thus the service life of bridges. Based on the information stored in the BEA database, the service life of bridge structural members in certain service life conditions may be estimated. For example, the real service life of bridge members as a function of the outside airs temperature at the time of the concrete casting. The information stored in the database may also be used in the development of a damage growth model based on the assessed condition at the time of inspection.

Keywords: Bridges, Service Life, Bridge Structural Member, Bridge Management, Database, Estimated Service Life, Damage Type, Damage Cause.

1. Introduction

It is generally expected that during their service life, bridges can fulfil certain demands such as traffic safety, continuous traffic flow and a designed load bearing capacity. Regular and systematic inspection of the existing bridge stock should be performed in order to verify that such demands are met at all times.

2. Relational database

The Windows - ACCESS database, BEA (Bridge Element Analysis), specially developed for the needs and requirements imposed by this research project, deliberately uses the same codes, definitions and terms as used by the Swedish National Road Administration. The BEA database is described in detail under chapter four in the Licentiate Thesis "Konstbyggnaders reella livslängd". The database BEA has great development possibilities. New objects can be created without difficulties. The performance can be improved if that becomes a priority, for example, through division of the database or better query design. Many queries have developed during the investigation. This is mainly due to the many questions of issues and reports that have occurred throughout the project.

3. Damage picture in the investigation

3747 bridge inspection remarks on the 353 investigated bridges have brought forward 2980 damage remarks where type- and cause of damage were stated and 767 remarks where the structural members were considered flawless at the time of inspection. Even if the results are not significant for the entire country, they are giving a clear indication of the general condition of the bridges in certain parts of Sweden.

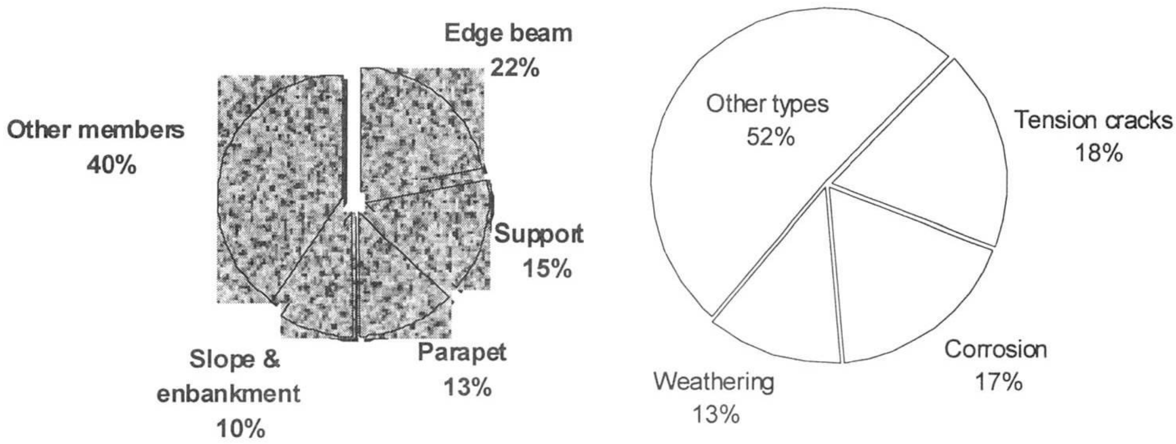


Fig. 5 *Percentage distribution of the damage types remarks on the bridges' different structural members, all condition classes.*

4. Conclusion and final comments

Obviously, BEA database can be used to achieve important information about the service life of bridges and their structural members. The historical information from former bridge inspections can be used to determine the growth of damages in time, certain service environment and bridge generation. The database can be used to examine, if information and data like geographical location traffic and weather data at casting, may influence damage growth and therefore effect on the service life of bridge structural members and also the service life of bridges. For the 353 bridges in the study, 22% of all inspection remarks are related to the structural member "Edge beam". The Swedish design and construction method of edge beams has to be improved as regarding durability. Based on the information in the database BEA, the service life of bridge structural members may even be estimated with a modified factor method, not presented in this paper. The information in the BEA database is very useful but not, however, representative for the whole country. The database should be completed with more bridges situated in different parts of Sweden.

It is also important to note that the heart of any management system, the database, is highly dependent upon the information put into them. The quality, and not neccesarily the quantity of information is essential when it comes to predicting damage growth.

Bridge Databank and Computer Technique

Tien PHUNG MANH
Civil Engineer, Ph.D.
RITST
Ho Chi Minh city, Vietnam

Tien Phung Manh, born 1965, received his civil engineering and Ph.D. degree from the Zilina University in Zilina, Slovakia. He works at the Research Institute for Transportation Science and Technology (RITST) in Vietnam. He researches failures, the load carrying capacity and the bridge management system.

Summary

Keeping archives, the observation and the processing of information on bridge objects are important activities of the bridge management during their whole service life. The good quality bridge databank will become one of the main sources of providing complete information on the different aspects of bridge objects. The object of this paper is to present the basic structure of the bridge databank. The way of using of the computational technology for the creation of the bridge databank, the way of the observation and analysis in the bridge databank are also being presented in this article.

Keywords: Bridge databank; management system; computer technique.

Astract

The bridge object belongs to the important object of the transport network. Therefore the incorporation of the bridge construction into the road communication from the viewpoint of safety and reliability of operation must also be as such it should not be the limiting element of the road efficiency. From this viewpoint, keeping archives, the observation and the processing of information on bridge objects are important activities of the bridge management during their whole existence. The good quality bridge databank will become one of the main sources of providing complete information on the different aspects of bridge objects, on the basis of which the bridge management may decide on their maintenance, modifications or reconstruction in time, in a quicker and more economical way.

At present, the computational technology is being developed in both aspects (hardware and software). There are various computational programs making it possible to work with data. Therefore the application of the computational technology on the creation of the bridge databank will become an inevitable task.

Every bridge management system contains many main modules: collection of data, keeping and processing of data, deciding module. The structure of these modules has less or more effect on the efficiency of the bridge management. The aim of this section is to deal with the structure of the bridge databank – the main module of the bridge management system. Some conditions, which must be taken carefully at the creating of the bridge databank, are dealt in this section.

Different bridge owners have different needs, therefore the structure of a bridge databank may be different. According to the analysis in this papers, the basic project of the bridge databank could be created with various parts (general data of the bridge, designs, the way of the construction, load and load carrying capacity, failure rate, service life and reliability) as it is presented in this section.

Over the years, some agencies have attempted to systematize data on structures using classical paper filling schemes to contain condensed structural data that is regularly needed for the administration and preservation of structures. By this system, keeping archives, the observation and the processing of information on certain bridge or on selection group of bridges are very difficult and it takes much time and money for these activities. Today, the computational technology is being developed in both aspects (hardware and software). There are various computational programs making it possible to work with data. Therefore, the choosing of the computational program to create the quality databank, which meets the mentioned conditions, is now a main problem.

According to the analysis in this article, the bridge databank formed by means of ACCESS 7.0 could become a suitable, useful and effective databank. It may have a convenient and logical structure. The bridge databank could be formed very easy and quickly.

Main parts of the data management system created in the ACCESS environment are various tables, queries, forms, reports and macros. The tables store different information on the every viewpoint of the bridge objects. The queries contain various sub databases formed on the base of the created tables by means of the different relations. The queries are used to view, change, and analyze data in different ways. They can also be used as the source of records for forms' and reports. Therefore the users could take various information and data from various existing tables in the bridge databank and create the group of the necessary data of the researched bridge objects. The forms are the main environments of the bridge databank for inputting and updating of the data. The reports help to give out various results from the processing of the data. In this contribution, the main steps for creating of tables, some easy queries, forms and reports in the bridge databank are presented too.

The bridge databank – the bridge database formed by means of the computational programs MS ACCESS could contain more text and graphic information on all bridge objects. On the base of the efficiency of the computational technology, every bridge managers could perform some different analyses of this bridge databank from various viewpoints (for example searching and selection of certain information on the concrete bridge object from any observed viewpoint: designs, the way of construction, resord, load and load capacity, failure rate, service life and reliability) very quickly by means of several queries. The users may create the necessary sub-database of several bridge objects from the created bridge databank according to certain criteria for their evaluation.

On the Free Vibration of Honeycomb Sandwich Plates

Brahim ATTAF
Associate Professor
University of Blida
Blida, Algeria

Brahim Attaf, born 1959, received in 1990 his civil engineering PhD degree from the Univ. of Surrey, UK. Since then, he joined the Univ. of Blida, Algeria, where he is investigating the vibration, stability and delamination of composite plates and sandwich panels.

Summary

The aim of this paper is to improve the dynamic effects of geometric design variables on a honeycomb sandwich plate. The variables of the honeycomb core were radius and thickness of the hexagonal cell while the mass of the honeycomb sandwich plate was kept constant. In addition, an attempt has been made to investigate the effect of material alteration relative to the upper and lower facings.

Keywords: Free vibration; sandwich plate; laminated facings; honeycomb core dimensions; finite element analysis.

1. Introduction

The increase or decrease in the natural frequency will depend on several design variables. Besides the material properties, the designer must consider the ratio r/L (honeycomb cell radius/plate length) and the ratio H/e (core thickness/facing thickness). All of these design variables will affect the sandwich plate natural frequencies. It is, therefore, required to undertake parameter studies which provide the means of selection and design of lightweight sandwich plates. However, difficulties inherent to transverse shear deformation, anisotropy of material and boundary conditions constitute a complex and tedious analysis and this make the solution of the equation system impossible. Finite element technique was, therefore, suggested to overcome these difficulties.

2. Numerical results and discussion

2.1 Vibration modes of homogeneous and sandwich plates

Two plate constructions having the same material (aluminium), same mass and same boundary conditions (fully clamped) were investigated. The former plate construction was thin and homogeneous; whereas the latter construction was a honeycomb sandwich plate. It was noted that the natural frequencies of a sandwich plate are greater than those of a homogeneous one. This gain in frequency is directly related to H, which rise the natural frequencies of the sandwich plate without materially increasing its mass. The first four mode shapes for both plates were seen to be identical.

2.2 Influence of honeycomb cell radius on the sandwich plate natural frequencies

According to *Fig.* 1, it can be noted that the frequency ratio Δ_i (*i=1,2,3,4*) decreases in hyperbolic form. Seen that Δ_i is high for small values of *r/L*; it is, therefore, recommended to choose the smallest practical value of *r/L*.

2.3 Effect of core thickness on the sandwich plate natural frequencies

According to *Fig.* 2, the ratio Δ_i increases with *H/e* in logarithmic form. For small values of *H/e* (less than 25), the natural frequencies converge to the same value. Whereas, for high values of *H/e*, the condition of divergence is clearly observed.

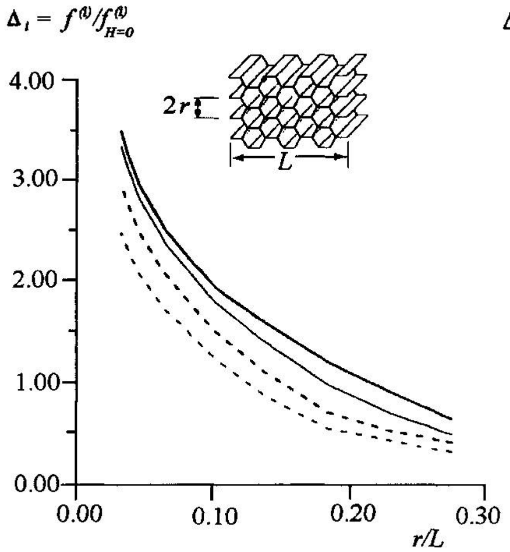


Fig.1 Frequency ratio Δ_i versus hexagonal cell ratio r/L for aluminium honeycomb plate. Frequency mode: (——)1st; (——)2nd; (– – –)3rd; (------)4th.

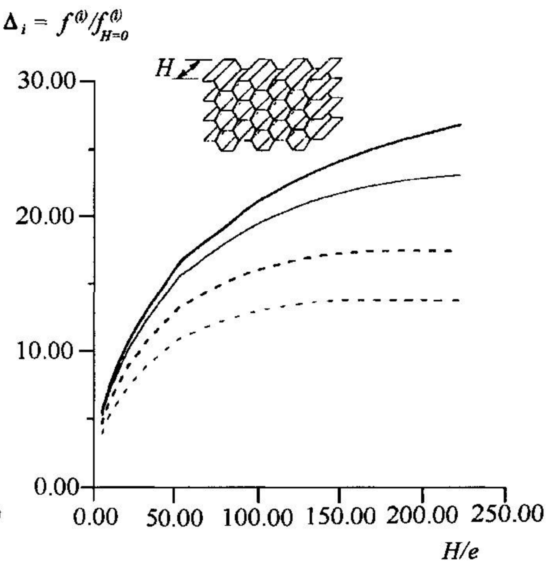


Fig.2 Frequency ratio Δ_i versus sandwich thickeness ratio H/e for all aluminium sandwich plate Frequency mode: as Fig.1.

2.4 Effect of facing material on the sandwich plate natural frequencies

A honeycombed sandwich plate with laminated composite facings was fully investigated. The source for increasing frequency and reducing vibration amplitude levels without introducing weight penalty is believed to be related to the fibre reinforcements which must be tailored in the plane where they will be most effective.

3. Conclusion

The present analysis reinforces the fact that vibration behaviour of complex systems must not be dependent upon one analysis procedure only. Comprehensive modelling of a finite element solution from an experimental procedure should be undertaken before parameter studies are made.

Virtual Prototyping in the Construction Industry

Bruno FEIJO
Professor
PUC-Rio & Uerj
Rio, RJ, Brasil

Bruno Feijó, born 1951, received his Aeronautics engineering degree from ITA (1975) and PhD degree from Imperial College (1988). He works in the areas of CAD, computer graphics and Information Technology.

Sérgio SCHEER
Professor
CESEC, UFPR
Curitiba, PR, Brasil

Sérgio Scheer, born 1957, received his civil engineering degree from UFPR (1980) and PhD degree from PUC-Rio (1993). He works in the area of CAD systems for civil engineering and mechanics.

Summary

The aim of virtual prototyping is to build a full virtual artifact in such a way that design and manufacturing problems are anticipated and discussed within a cooperative work environment This paper presents virtual prototyping as the most adequate technology for the construction industry in the next decade.

Keywords: CAD, virtual prototyping, integrated design

1. Introduction

Virtual prototypes (*i.e.* complete 3D models) have been using in the mechanical industry for many years. Perhaps the most recent and impressive example is the Boeing 777 almost entirely represented by a 3D CAD model. Nevertheless, a virtual prototype is much more than a complete 3D model of the artifact. Virtual prototyping requires 3D models that are able of integrating several sectors of a company and demands high-end technology for virtual reality environments, virtual humans and distributed environments. Moreover, a virtual prototype works as a spatial database that can be queried by anyone in the enterprise through the computer network.

2. Virtual Prototyping

The objects of the virtual artifact have several types of attributes, such as geometric attributes, design intent attributes, manufacturing attributes, cost attributes, pointers to part numbers and documentation references. It is clear from Fig. 1 that the virtual prototype is distributed over several networks with different platforms, operating systems and design teams.

Virtual prototyping should consider geometry buses and object-distributed computing. A Geometry Bus allows designers to use different CAD programs in the network. ACIS [1] and CORBA have been proposed as a geometry bus and distributed object architecture for integrated CAD systems respectively [2].

Essentially, the Product Structure shown in Fig.1 is a collection of pointers to 3D models and 2D drawings. The data exchange format STEP can be used to present components as a text description or a 3D object. STEP files can be browsed in the intranet.

Virtual prototyping requires VR technology. Virtual Reality systems provide immersive environments where the user experiences a sense of immersion. This is the case of using a head-mounted display (HMD) or a BOOM (Binocular Omni-Orientation Monitor). Fig. 1 illustrates an immersive environment where a designer incorporates an avatar (*i.e.* a virtual copy of the user) using the system Jack for virtual humans. Designers can use virtual humans in a number of ways, such as: accident simulation, workplace assessment, human strength analysis, and check of maintenance procedures in areas of difficult access.

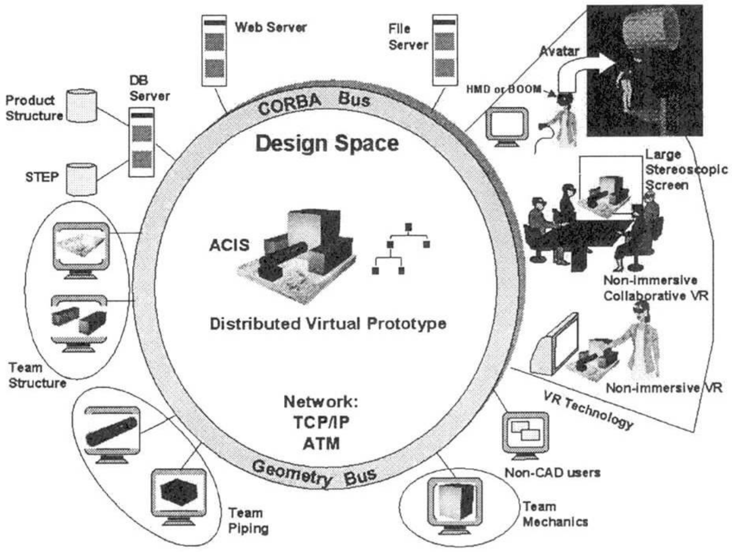


Fig. 1 Example of a distributed virtual prototype

A more rigorous definition of virtual environments and a practical guide for engineers who want to explore the possibilities of the VR technology can be found elsewhere [3].

3. Conclusions

The search for quality in structural engineering in the coming decade should consider its manifold activities, which are integrated amongst themselves, such as design, planning, construction, operation and maintenance. This integration should be considered during the design phase and the practice of virtual prototyping seems to be the most adequate approach to this question. Virtual prototypes also allow visibility to the public in real time through the internet – an important concern when environmental, social, human and aesthetic factors are critical.

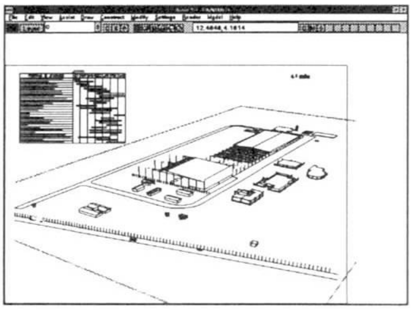


Fig. 2 Planning – 4th month

Several previous experiences by the authors support the recommendations presented in this paper. For instance, the authors had a stimulating experience with a large Brazilian construction company (CBPO), where they developed a computer system integrating 3D models with planning networks [4]. This system revealed more adequate construction methods for a factory of metallic cans and lead to a schedule two months shorter than the one obtained by the conventional planning methods, as shown in Fig. 2.

4. References

[1] Spatial Technology, *ACIS 3D Toolkit Version 2.1*, Spatial Technology Inc., USA, 1996.

[2] Regli, W. C., "Intranet-enabled Computer-Aided Design", *IEEE Internet Computing*, Vol. 1, No. 1, Jan-Feb 1997, pp. 39-50. [Also in http://www.computer.org/ internet/ backissu.htm].

[3] Feijo, B., "Virtual Environments for CAD Systems", In C. Tasso, E.R. Arantes e Oliveira (eds.), *Development of Knowledge-based Systems for Engineering*, Springer-Verlag, Udine, Italy, 1998, pp. 183-200.

[4] Feijo, B., P.C.R. Gomes, J. Bento and S. Scheer, "CAD for process innovation in the construction industry", *Structural Engineering and Mechanics*, Techno-Press, Taejon, Korea, Vol. 4, No. 6, 1996, pp. 717-729.

Analysis of Plated Structures by Coupling Techniques

Hassan M.H. IBRAHIM
Lecturer of Concrete Structures
Suez Canal University
Port-Said, Egypt

Hassan M.H. IBRAHIM, born 1964, received his
* B.Sc. degree (1987) and M.Sc. degree (1991) from Suez Canal University, Port-Said, Egypt,
* Ph.D. degree (1996) from Suez Canal University under the channel system program with Ottawa University, Ontario, Canada.

Summary

In recent years various types of bridge structures have been highly developed and there has been an increasing demand for a new, effective method of analysis. It is often difficult to cope with such problems independently by a single numerical method, and a practically effective method of analysis is required. Many researchers have worked on the hybrid techniques. In those techniques, coupling of two of the well-known numerical methods such as boundary element, finite strip, finite difference, and finite element methods is implemented. Their publications have created controversies over the effectiveness of the coupling technique. The author presents an overview of the past researches including his own in the area of coupling of those numerical methods for the analysis of thin-plated structures, particularly used in highway bridges. The potentiality of hybrid techniques in solving many problems where the distinctive advantages of those methods is effectively utilized.

Keywords: Hybrid techniques; Coupling; Thin plates; Highway bridges; Boundary elements.

1. Abstract

In the last two decades, various types of bridge structures, composed of thin plates such as box-girder and plate-girder bridges, have been highly developed all over the world and there has been an increasing necessity for a new, effective method of analysis. Structural engineers are requested to analyze those large-scale compound structures with stress concentrating parts, cracks, beam and plate-like components, contact parts and so on. In those structures, the stress distributions in the plate elements are most likely to deviate from those predicted by the bending theory or the torsion-bending theory. It is also often difficult to analyze such problems independently by a single numerical technique, and hence a practically effective method of analysis is required. The experience indicates that in the numerical discretization of this problem there are many primary solution techniques. Those techniques are the boundary element method, finite element method, finite difference method, finite strip method, transfer matrix method, and thin walled segment method. Each technique is applicable only within a certain range. Outside this range other technique seems to be more efficient.

If the structure has constant cross section and its end support condition does not change transversely, the finite strip method has proven to be the most efficient method. If the structure has any irregularities, the finite strip method is no longer valid and other method has to be used. However, the major drawback of this method is, no change in material properties of each strip of the bridge along its length is allowed. On the other hand, the finite element has proven to be the most effective numerical tool for analyzing plated structures. However, the efficiency of the method needs to be improved for structures subjected mainly to moving loads. Moreover, under the moving load's condition, the mesh for the bridge deck should be further refined otherwise accuracy of the results tends to decrease significantly. The mesh needs also to be changed as the loads are moved. The boundary element method offers important advantages over domain-type methods. The most interesting features of boundary element are that a much smaller resulting system of equations and a considerable reduction in the data required to solve the problem is obtainable. Another advantage is that, the equations need only be applied to the boundary and the solution is more accurate than those from other methods. It is also effective in simulating local effects of wheel loads. With regard to the finite element, the accuracy of the boundary element, if not better, is equally good. The main disadvantage of the method is, however, the difficulties encountered in non homogeneous problem, i.e., finding the fundamental solutions and defining the interfaces.

In view of these aspects, a considerable expansion in computational power can be obtained if one resorts to hybrid analysis schemes which retain the main advantages of any two of the coupled numerical methods and eliminate their respective disadvantages. The necessity of coupling numerical methods arises from the deficiencies and limitations of each numerical method when it stands alone for analyzing structural problems especially for high way bridge structures. In order to profit from their advantages, a combination between them seems to be ideal. Such a combination should allow for the use of the most appropriate technique over each region of the problem with a reduced number of operations and without compromise in accuracy.

The fundamental difference in the various coupling techniques occurs in the treatment of the interface condition. A linking between the methods is possible in principle simply by applying the appropriate interface conditions between the two regions occupied by the two techniques. A coupling procedure may be performed by simply linking together the two sets of linear algebraic equations obtained from the two numerical techniques.

As shown by many researchers, the boundary element method is introduced as an efficient, simple and more accurate technique when coupled with other numerical methods. It could be used to overcome the deficiencies of applying numerical methods to a certain part of the domain of the problem. Since no method can stand alone for solving most of engineering problems, a structural analysis method based on a combined use of the boundary element method and other numerical method is needed. The coupling techniques ensure the best use and compensate drawbacks of the numerical methods to be coupled. Therefore, this paper presents the hybrid stress analysis procedure that combines the well-known numerical methods with the boundary element method. The basic theory behind the applications and the execution of the coupling technique to different bridge structures is also presented. This work introduces also the coupling of the boundary element method with other numerical methods, especially the finite element method, as an efficient and promising technique. The proposed technique is well-suited for computer aided analysis and to be implemented in many commercial software's. However, much work still needed to be done to streamline the computational process and clarify theoretical and practical aspects of the coupling techniques.

The Role of Equilibrium Analysis in Structural Assessment

Bill HARVEY
Professor
University of Exeter
Exeter, UK

Born 1947, BSc and PhD in Civil Engineering from the Univ. of Leeds. Worked on bridge construction from 1971-77. University of Dundee 1977-95. Director, Wolfson Bridge Research Unit 1989 Head of Department 1991. University of Exeter from 1995

Summary

Equilibrium analysis in its simplest form is a mechanical process of hang weights from strings to represent the mass and geometry of a structure. In this form it was used from the days of Hook and Wren, but found its greatest exponent in Gaudi. The advent of microcomputers and spreadsheets offers the opportunity to build such models much more quickly. They are, of course, virtual models but the nodes can be moved with much greater ease.

The view of flow of force, which comes from a calculated model, is more complex and more complete than that from a physical string model. A complex structure, one that does not lie in a single vertical plane, is examined in some detail to explore some of these complications.

Keywords: Gravity, masonry, arch, buttress, equilibrium, thrust-line.

1. Equilibrium Analysis

Equilibrium analysis is the study of the flow of forces. It is common to use thrust lines and similar tools to visualise the output from modern finite element analyses but sketching thrust lines with the aid of a computer is very useful, at least for initial studies. There are disadvantages in this simple view of structural action and some of them will be discussed. Usually the advantages far outweigh the disadvantages.

Specialist programmes have been written for arch bridge analysis. They cannot easily be applied to others structures. The development of the spreadsheet has made it possible, and indeed quick and easy, to develop equilibrium analyses of complex and original structures.

The representation of the forces and the division of the structure into elements must be optimised. The forces are best represented as vectors positioned by moments. The process is one of accumulation of forces.

1.1 Visualisation

Visualisation of the flow of force is a complex issue. In two dimensions, the line of thrust or zone of thrust shows clearly whether the forces can be equilibrated in the structure. In three-dimensional skeletal structures it becomes necessary to rotate the view in order to explore the alignment of forces and structure. Modifications to the picture may be required. It will be necessary to represent the outlines of the structure and the path of the forces in a way, which is easily digested by the engineer.

Presenting the results of two-dimensional calculations is relatively straightforward. In three dimensions, the problem is more difficult. If every cross section is rectangular, two orthogonal views tell the whole story but that is rarely the case. It is convenient to draw just the perimeter of the mating face between elements. In most views, this provides an understandable representation of the structure.

Interaction with the model can be achieved by typing values into cells to adjust the redundant actions. This is slow, which detracts considerably from the rate at which understanding can grow. Alternatives include pick lists, slider bars, spin buttons etc. available from Excel 97.

1.2 Wells Cathedral Skew Buttresses

The east wall of the choir at Wells is supported by two flying buttresses, which extend eastwards and drop to a relatively flat leaded roof. Below, they are supported on slender columns, which are offset from the axis of the buttress.

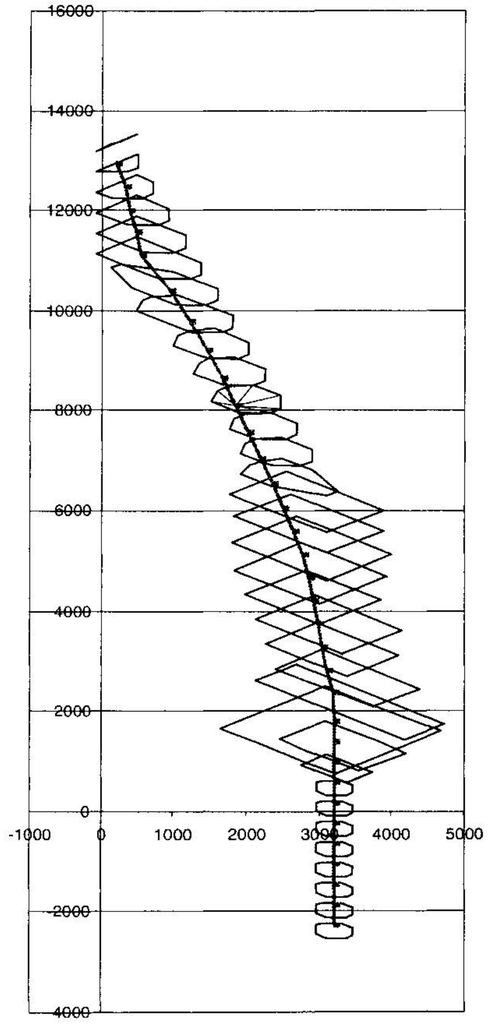


Figure 1 Buttress on Offset Pier

We have become used to ensuring that thrust lines run through appropriate points in a structure. The corresponding shear forces are usually small enough to be safely ignored. In a slender skeletal structure such as this, the shear may not act at the centroid of the section, or even at the centroid of that section which is in compression. There will thus be a twisting moment or wrench at any section. That twisting moment must be considered, even if the engineer then decides it is small enough to be ignored. The twist and shear is not easily visualised, nor is it easy to interpret.

Figure 8 shows an oblique view of a line of thrust in the buttress.

2. Discussion

A rather more complex model is quite manageable. It would entail introducing further points of interaction to deal with the additional redundancies. Structures that are not inherently skeletal are more difficult to deal with. The author is pursuing alternative forms of discretisation, interaction, calculation and visualisation. In the mean time, the models demonstrated offer a simple way of exploring potential behaviour in complex, particularly old, structures.

A number of issues are raised which leave difficult questions for the engineer. The interaction of a stiff structure with its more flexible surroundings is not well understood. Good models can highlight this but they can also help the engineer to apply judgement.

The three dimensional model of the Wells buttress is capable of dealing with further load systems, of which wind is most likely to be significant. Further work on the model will be allied to developing ideas on interaction and visualisation techniques. There is also potential for considering different models of details of the structure. One possibility is that the simple thrust line could be replaced with a three dimensional strut and tie model in critical regions.

Analysis of Prestressed Multi-Girder Bridge Decks

A. A. D. ALMEIDA
Graduate Student
PUC -Rio University
Rio de Janeiro, Brazil

J. L. ROEHL
Professor
PUC - Rio University
Rio de Janeiro, Brazil

Abstract

The design of highway multi-girder bridge decks includes in the static analysis the evaluation of the deformed shape and stresses, in every member, due to a standard set of vehicles according to the applicable code requirements. So, it is necessary to compute the extreme values of mechanical quantities, which occur for different moving load positions on the deck, taking into account the redundancies of the deck grid.

In general, the used procedures evaluate these effects defining a moving load train for each element, based on different load transversal distribution criteria, and then adopt the most severe load position in each situation. Others use a finite element deck model to determine the effect of transversal distribution and, in sequence, study each element separately. A rigorous procedure to account all the variables involved and incorporating the prestressing dimensioning with losses evaluation and admitting also eventual iterations, can take more time than the design schedule may allows, if a consistent and automatic procedure is not used.

Looking further, one realises that the capabilities of modern microcomputers, in data storage and in computational velocity, are present on the work desk of every structural engineer. Under this view one presents an analysis methodology, conveniently implemented, to compute the amount of prestressing and mild steel to the above mentioned bridge decks. A pre-processor is included to minimize the input of data task.

A specialized computer program for the analysis of simply supported multi-girder highway bridge decks is developed, and commented herein, to automate this design task. Where code requirements are necessary to evaluate the acceptance of the solution under study, one uses the Brazilian NBR-7187 .

A finite element grid model is used for the deck, and the moving load, formed by any arrangement of vertical concentrated or distributed loads (according to the applicable code requirements), moves step by step, on all deck surface. By a suitable data manager scheme, the load is distributed to the grid and displacement and stresses are computed for every successive load position; the extreme values are conveniently stored. All these effects are obtained on the grid redundant model by a conventional displacement method of analysis. The dead load effects evaluation also is made on the grid model, as well as the prestressing dimensioning.

The design of a prestressed bridge deck has to consider three peculiar situations which require a special attentions of the analyst:

- prestress varies along the length of the cables and is a time dependent problem;
- concrete casting schedule can be divided in three or more phases and cross sections proprieties vary from phase to phase.
- deck structural system also varies from one phase to another as the assembling of new elements changes the system redundancies.

For the case of multi-girder precasted simply supported bridge decks these pecularities are still more important because the larger number of bridges which use similar solutions with several span repetitions per place. For this reason one is encouraged to work on a specialized routine to analyze these systems in a consistent manner which handles all the design phases, as much as possible, on the same grid model. The proposed methodology and the subsequent implemented program allow one to carry a consistent analysis of simply-supported multi-girder prestressed concrete highway bridge decks, taking into account all these peculiarities including the stiffness redundancies of the slabs.

One example illustrates the application of the proposed methodology in comparison with an usual solution of the same case. One carries the analysis of a 43.10 m long simply supported highway bridge deck made of prestressed concrete, which has been designed and built in Brasil, sometime ago, using a less consistent procedure. It is shown an outlook of the program output which gives phase by phase, element by element, all the kinematics and internal forces and stresses of the grillage, including prestressing. Eventual hazard warnings show up where code provisions are violated. Several alternate solutions can be tested rapidly.