A first step towards an intelligent integrated design system in the building field

E. Brisson, Ph. Debras and P. Poyet

CSTB, Knowledge Base Group, BP. 141, 06561 Valbonne, France

Abstract

This article presents the work the Knowledge Base Group is achieving towards the integration of Artificial Intelligence based facilities in the Building design process. After an overview of the current state of the integrated design process, we describe the context and the technical guidelines to realize computer integrated software in the building design field. Then some tools are presented to model the knowledge (the HBDS method) and to implement such model in our Mips home-made knowledge modelling software platform (including object-oriented database management facilities, expert system reasoning facilities, hypertext edition facilities, 3D-design and 3D-view modules ...).

Finally we describe the Quakes application devoted to assess detached house anti-seismic capabilities during the design process. A deep conceptual model takes in charge all the semantic entities (columns, resistant panels, openings, ...) involved in the anti-seismic expertise. Using both this conceptual model description of a detached house and the 3D design tool, we input the project. Then the seismic expertise is driven in a divide and conquer approach and records the alleged configuration recognized automatically linked to the corresponding section of the building regulation.

1. INTRODUCTION

Many computer systems with their own features, their own data representation techniques and models, their own goals, concurrently exist. A lack of productivity emerges from this inherent diversity, as computer systems and computer programs have a disappointing lack of inter-exchangeability and as standardizing processes face enormous difficulty and commercial stakes. However integration appears for most of manufacturing and engineering activities a key issue. Let us mention deep object-oriented models for instance, possibly representing the kernel on which an agreement should be reached , for which little help is currently available from standardizing committees (e.g. STEP / ISO) and only fragmented solutions brought from valuable attempts such as the EXPRESS language.

In this paper we focus on the design stage in which a basic common core can be identified, representing the common understanding the people have of a project throughout its evolving stages, supplemented with particular views accounting for private data and personal entity relationships (i.e. particular to a given actor). We describe our home made software platform, the HBDS knowledge representation method and the QUAKES application showing the integration of a deep semantical model viewed by the anti-seismic aspect and allowing the design of detached houses according to the French regulation.

2. THE INTEGRATED DESIGN PROCESS

2.1. Technical Context

Building design is a good example of a co-operative decision making process, involving various skills representing the aspects at different periods of time throughout the life-cycle of the project. Moreover, the intimate project understanding heavily relies on the actors' cognitive means, themselves strongly influenced and shaped by their intellectual tools and proficiencies referred to as views. We argue that software modelling and integration of such heterogeneous decision making processes can now readily be achieved, leading to much more than a simple collection of tools and systems designed separately. Sophisticated data modelling techniques should account for the deep relationships and for the structural ordering of the entities involved by any of the aspects, moreover recording the project alterations throughout the life-cycle, and serve as a basis for the views (e.g. graphic, topological, logical, numerical, etc.). Nevertheless, a common understanding of the data is only a first and limited step on the road of true knowledge-integration, and non procedural models of design activities have to be devised to handle actors' negotiations under common and conflicting resource allocations under ever changing conditions. In that respect, A.I.-based techniques provide a sound basis both for the data representation purposes (including sophisticated object-based models) and for the reasoning schema offering distributed mechanisms (e.g. blackboard, contract net, etc.), non-monotonic reasoning under evolving and conscious hypotheses, assumption-based labelling of derived properties, etc. Such an environment and these software facilities should enable the actors to gain support throughout all phases of their activities, modelling the work domain thanks to the reachable network of the time-dependent object worlds with their specific views representing as many knowledge indexes as required by the designers diversity, and providing non-monotonic objective and decision functions for reasoning capabilities [1-2].

2.2. Technical Guidelines

The deep data model should convey various types of fundamental informations, including : the entities involved by a given project, their content (i.e. the data stricto sensu) and their relationships, thus representing the work domain modelled by the network of inter-dependent concepts and carrying the semantic, the topological links applying on these entities and addressing the level of spatial dependency, and the geometrical layer storing the set of shapes (2D or 3D) involved in the graphic representation of the concept, if appropriate. These are the most conspicuous features of the data model, but they need to be supplemented both by the aspect facility, enabling the user with special access modes and browsing facilities of the data network according to his cognitive perception of the project, and by the life-cycle property labelling the project content (i.e. data and structure) according to the relevant project phases.

Such a data model is really the hard core of a truly software integrated approach and can benefit from the EC COMBINE project results. It can provide a means to merge the various isolated conceptual models elaborated within each architectural or technical sub-domain, and represent the strong common basis well suited to achieve tools dependent activities, such as external and graphic displays of the model (i.e. basically what most of the available CAD systems do) acting as one of the side effects of the deep data structure, as dedicated computing facilities (i.e. typically what most of the performance evaluator codes do) based on ad-hoc (re-)interpretation of the entities and of their derived properties and meaning, or as technical project management and negotiation functions handling co-operative and inherently conflictual processes [3].

3. COMPUTER TOOLS FOR INTEGRATED SOFTWARES

3.1. The HBDS Knowledge Representation method

The HBDS (Hypergraph Base Data System) method has been developed at Paris VI university [4]. This method, available for the modelling of any kind of knowledge, consists in the application of different abstract mechanisms on real systems, building for instance. It provides a knowledge structure including the objects to be designed, methods for engineering calculations, rules of expert systems, information allowing the visualization of the entities, etc. This method is based on the theory of categories well-suited for eliminating distracting details from highly structured situation. The HBDS model is based on the following strategy to collect and to represent the knowledge of a system :

- to collect the entities and their relationships ;
- to synthesize in a rational manner (attributes, classes, relations) ;
- to build a global model (structure) open on the functional characteristics (figure 1).

The HBDS method appears as an inductive, deductive and hypothetical process. Induction allows the generalization. The hypothetical process takes in charge the means of identifying the relationships between the entities involved. The deduction theory anticipates the behaviours of the objects. This kind of data is very useful in a knowledge base system supported by object oriented languages such as our home made platform : MIPS or Many Integrated Paradigm System.

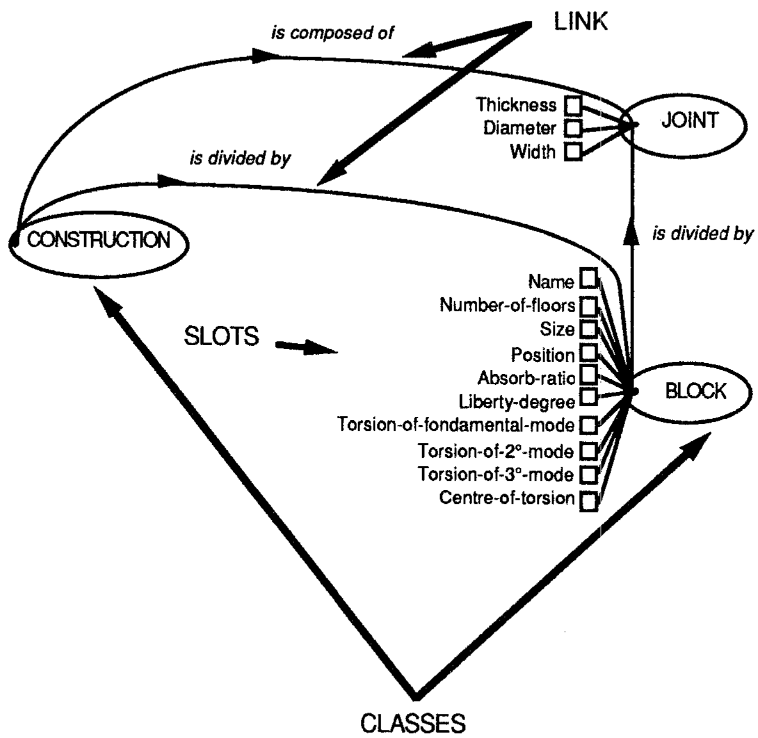


Figure 1 : Abstract models (classes) and the corresponding relationships (links).

3.2. The MIPS knowledge modelling software platform

The MIPS environment (figure 2) is a very efficient tool developed upon the Micro Ceyx basic object oriented language of the Le_Lisp System and the graphic interface AIDA shell. We present here an overview of the MIPS system through a representative subset of its fundamental concepts [5-6]:

- an object layer to implement HBDS structure using abstract objects (classes), slots (attributes), object slots (links) and mechanisms to instantiate concrete objects and relationships between these concrete objects. Abstract objects can be arranged within hierarchical structures (hierarchies) to give a higher semantical level allowing the inheritance of messages sent to concrete objects ;
- Mips expert systems topology, abstract models of expert systems devoted to design, simulation, diagnosis, documentary retrieval, or node processing. The reasoning facilities of each type of expert system are based on a set of associated messages ;
- A set of graphic facilities attached to the objects and to their slots (i.e. according to their type), allowing the automatic generation of user oriented dialogs for appropriate editing purposes ;
- A set of geometrical properties attached to the abstract objects allowing the design of specific CAD interface. The CAD tool should be viewed as an intelligent activity, answering to a

message of the MIPS system, and providing a complete CAD system depending on the objects we want to create ;

- A three dimensional viewer including wire representation, covered face visualization and color rendering. The visualization of a project is driven by the semantical network of its concrete objects. Sending the "view" message to a concrete object makes the system travel through the network and display the geometrical objects attached to the encountered concrete objects ;
- An expert system generator toolbox taking advantage of the reflexive development policies, allowing the management of expert system life cycle, connections between them and co-operation leading multi-expertise [7];
- A set of retrieval and hypertext facilities to handle documentary databases (e.g. Unified Code of Practice of the french building regulation), thus offering various access modes to documentary corpus (indexation, graphic access, local dictionaries) available for different data types (text, images, array, formula, etc...) and associating this primary information to intelligent softwares (QUAKES for instance) [8].

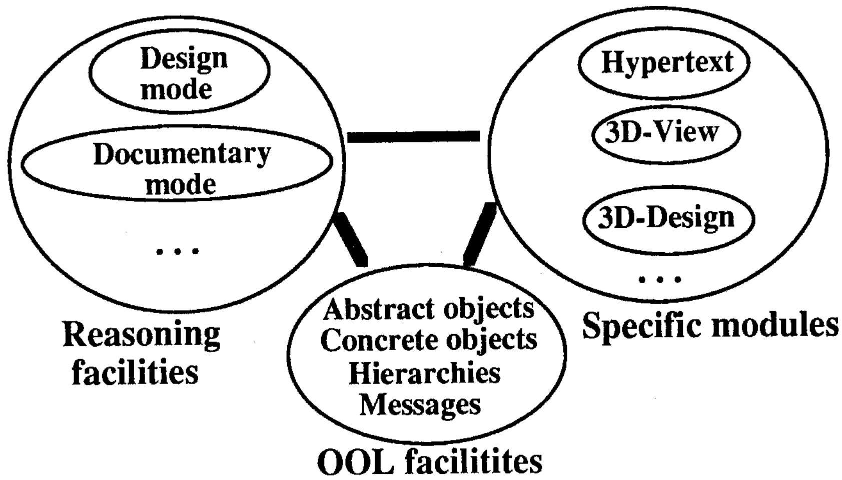


Figure 2 : The complete MIPS environment.

4. THE QUAKES APPLICATION

4.1. Background

Dramatic earthquakes regularly occurred since the 12th century in the South East of France and require that suitable measures be recommended to ensure the protection of the real estate, of the economic wealth of the region and of course, most important, of the population. The French Scientific and Technical Center for Building (CSTB) has been involved since the very beginning as a member and contributor of the different technical committees in charge of the regulation. As a public research center working on computer science applications in the construction field, we deemed useful to launch a project to devise an intelligent software providing assistance to the building designer in this field.

4.2. Quakes

This application aims at helping foremen, architects and professionals, to comply with the requirements coming from the 1990 anti-seismic detached houses measures, and to provide facilities to obtain a satisfactory design through a straightforward interaction with the expert system. We developed a conceptual model including the building semantical entities with their geometrical definition and the necessary properties for the dialog interface. The project is checked using a task tree in charge of the finest design controls, and finally the various design errors are gathered to provide the user with a detailed set of explanations related to the corresponding items of the regulation.

4.2.1. The conceptual model

Before considering the implementation issue, a HBDS structure can be devised from the many concepts involved in the anti-seismic design activity and related to :

- the geological basement properties and the environmental conditions of the future construction ;
- the constructive options of the design and the building outlines ;
- the wall clamping technique used to ensure the tying of the structural elements of the design (e.g. walls) ;
- the characteristics of the elements not contributing to the structural resistance of the work ;
- and finally, the products involved in the technological choices leading to the effective realization of the building.

4.2.2 The MIPS model

The real project is directly generated from the structural ordering of the abstract data model, thanks to the "ask" message sent to the *project* object (figure 3) representing the root of the structural network of the complete set of sub-objects involved in the QUAKES model. The "ask" message is propagated to the slots and allows :

- to provide an interface (if the slot is askable) corresponding to the type (integer, string, etc.) and to the characteristics (possible values, question, title, etc.) of the slot ;
- to apply a function (if it is computable) and to store the result ;
- to instantiate a concrete object (if the type of the slot is object) and to propagate the "ask" message to it. If a link to a geometrical definition exists, the MIPSCAD editor will provide a geometrical entity which will be linked to it (figure 4) ;
- to pop a hierarchy (if the type is hierarchy) in which an abstract object can be selected to instantiate a corresponding concrete object (figure 5).

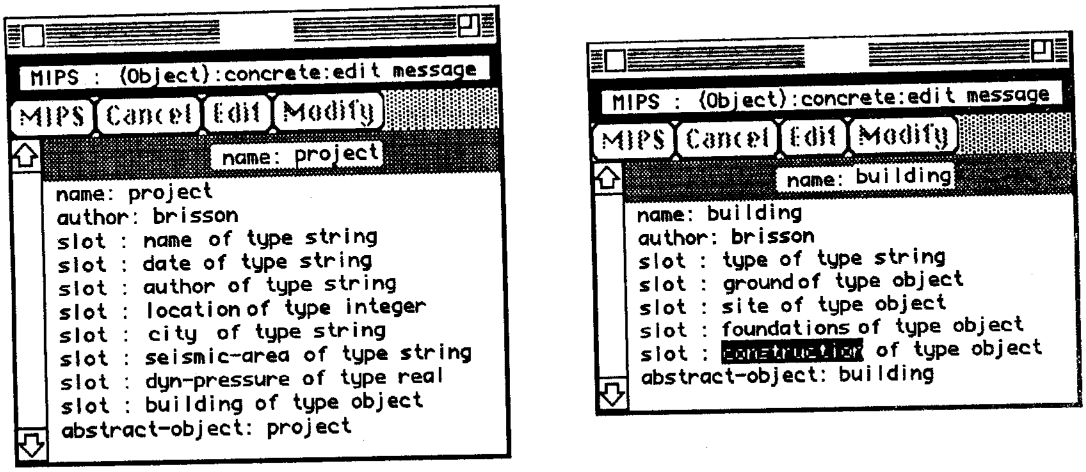


Figure 3 : The concrete objects PROJECT and BUILDING

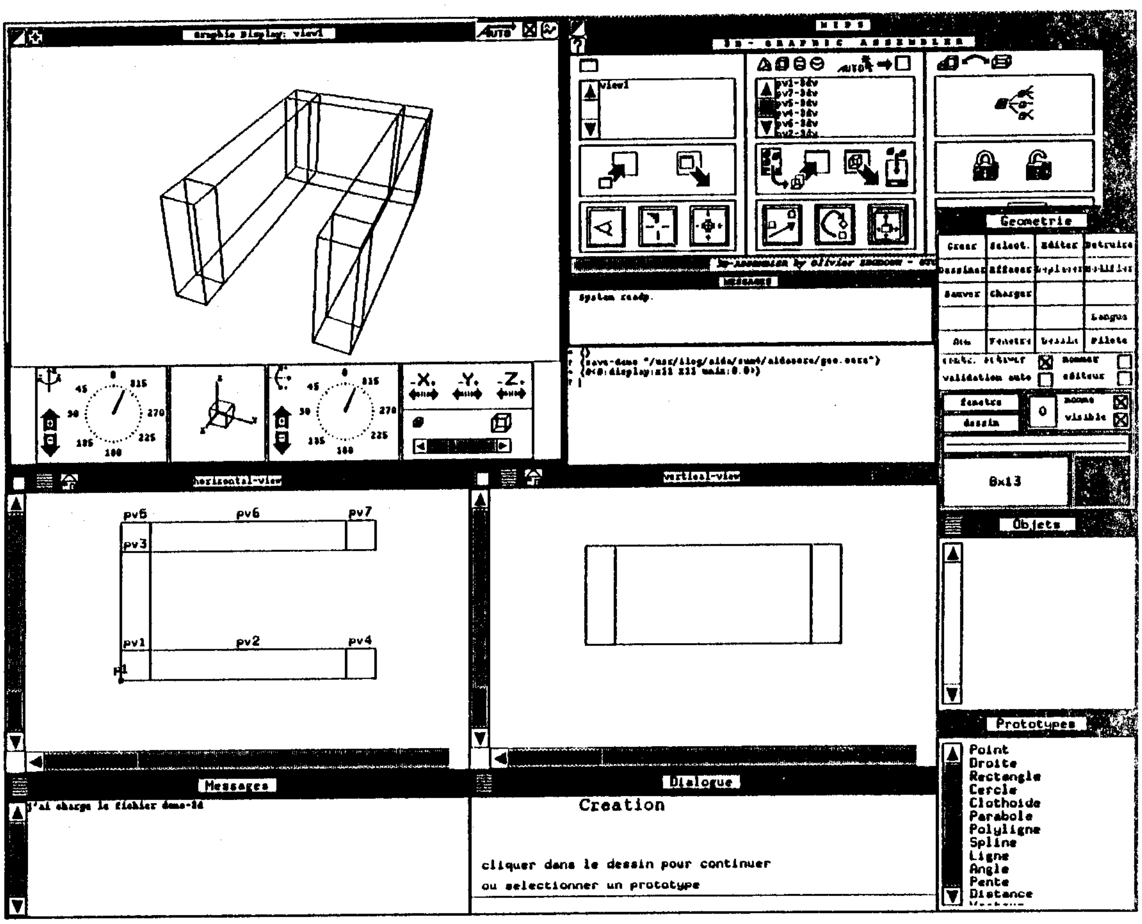


Figure 4 : The MIPSCAD editor.

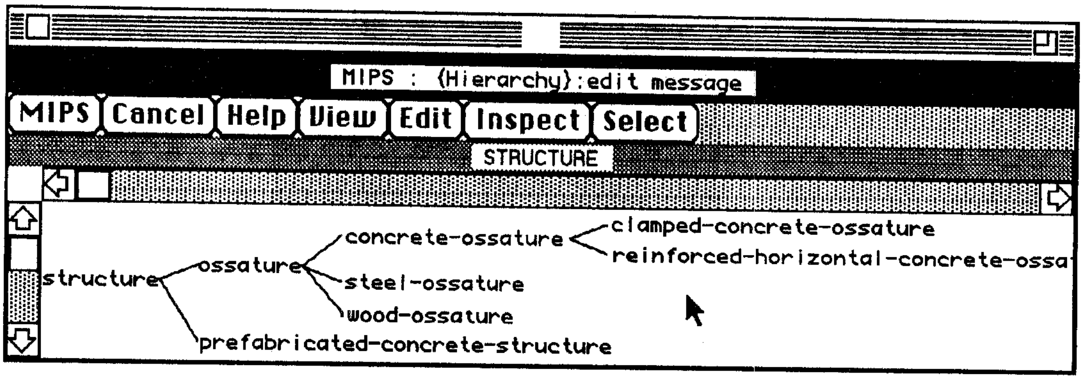


Figure 5 : A MIPS hierarchy

We have provided so far a very schematic overview of the object-oriented model of the QUAKES software, but we underlined the key notions involved and showed the most prominent concepts representing essential entry points for the user interaction. Of course many other objects contribute to the model such as soil types, foundation models, possible links between soils and foundations, site prototypes, resistant panel alternatives, horizontal and vertical clamping types and their related connections, door or window-frames, materials, non-structural elements, blocks, joints, etc.

4.2.3. Reasoning functions

The MIPS design mode implements the divide and conquer approach to solve design problems. The global problem is sub-divided in a hierarchy of tasks, each one of them contributing, thanks to a set of rules stored in a rule base, to the local solution of a sub-problem of the initial goal. When a rule is fired QUAKES creates a particular object named an anomaly, which is the reflect of a design defect, labelled with the sets of concrete objects involved. When the user requests the display of an anomaly, the system creates a special interactive device summarizing information related to the sets of instances that fired the rule and to generic data related to the rule itself (figure 6). The user may select the regulation reference to open automatically a hypertext representation of the concerned regulation item. The figure 7 shows a connection to the paragraph 4,22 of the "PS-MI" Unified Code of Practice. Finally, the QUAKES system can produce a comprehensive report listing all the observed anomalies and provides complementary advices to facilitate the correction of the sundry flaws detected.

4.3. Summary

In order to help project designers to comply easily with the regulation and to check the correctness of any given project against the legal dispositions, we developed the QUAKES software, a computer assisted consultant handling a complex object-oriented representation of the construction, able to verify the overall characteristics of environmental, structural and non structural parameters of detached houses. This application allows to show the usefulness of object oriented tools in the design of complex engineering software.

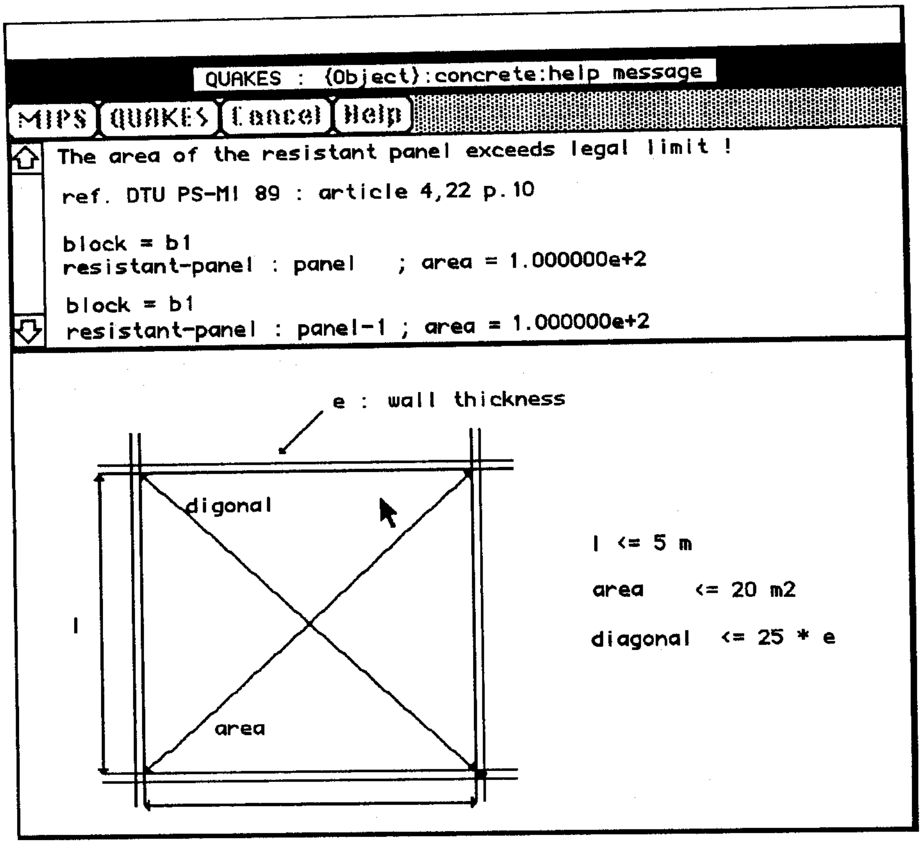
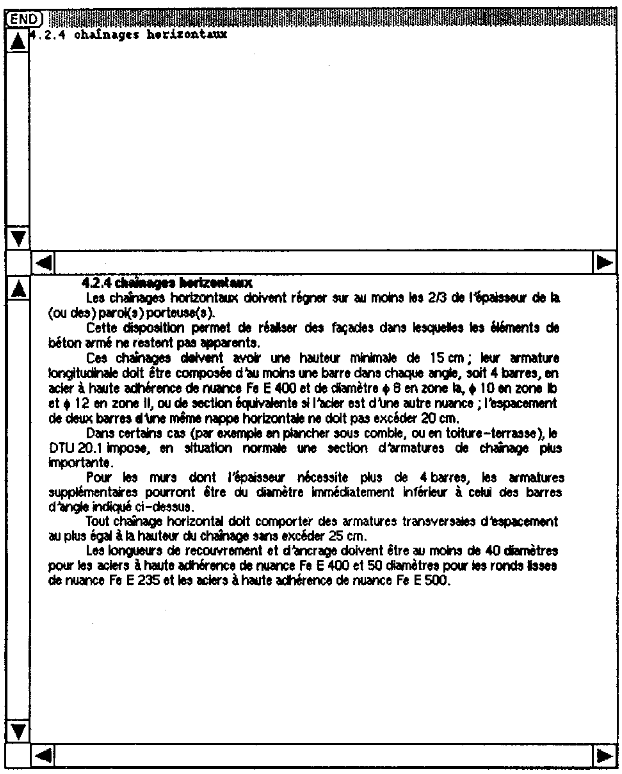


Figure 6 : An example of anomaly interface.



4.2.4 chaînages horizontaux

Les chaînages horizontaux doivent régner sur au moins les 2/3 de l'épaisseur de la (ou des) paroi(s) porteuse(s).

Cette disposition permet de réaliser des façades dans lesquelles les éléments de béton armé ne restent pas apparents.

Ces chaînages doivent avoir une hauteur minimale de 15 cm ; leur armature longitudinale doit être composée d'au moins une barre dans chaque angle, soit 4 barres, en acier à haute adhérence de nuance Fe E 400 et de diamètre ϕ 8 en zone Ia, ϕ 10 en zone Ib et ϕ 12 en zone II, ou de section équivalente si l'acier est d'une autre nuance ; l'espacement de deux barres d'une même nappe horizontale ne doit pas excéder 20 cm.

Dans certains cas (par exemple en plancher sous comble, ou en toiture-terrasse), le DTU 20.1 impose, en situation normale une section d'armatures de chaînage plus importante.

Pour les murs dont l'épaisseur nécessite plus de 4 barres, les armatures supplémentaires pourront être du diamètre immédiatement inférieur à celui des barres d'angle indiqué ci-dessus.

Tout chaînage horizontal doit comporter des armatures transversales d'espacement au plus égal à la hauteur du chaînage sans excéder 25 cm.

Les longueurs de recouvrement et d'ancrage doivent être au moins de 40 diamètres pour les aciers à haute adhérence de nuance Fe E 400 et 50 diamètres pour les ronds lisses de nuance Fe E 235 et les aciers à haute adhérence de nuance Fe E 500.

Figure 7 : An illustration of the hypertext link

5. CONCLUSION

Creating smart integrated environments should be considered as a major research challenge requiring deep understanding of the computer science techniques involved and of the construction field specificities. The global efficiency of the construction sector can also be improved, thus leading to cheaper and better buildings. The current situation is that for a long time, the traditional place of computer applications in the sector has been limited to numerical analysis (e.g. structural, thermal or acoustical modelling - engineer workpackages), drafting systems (e.g. architectural packages), and managerial environment (e.g. bills of quantity, procurement modules, etc.). In this context, where island of automation and computerization have emerged, the lack of integrated functions is particularly obvious, and severely hampers the productivity of the sector, and the efficiency of the individual actors.

7. REFERENCES

1. P. Poyet, Intelligence Artificielle et Bâtiment : Les Activités du CSTB. The Journal of CIB - Building Research and Practice 18 (4), 226-239 (1990).
2. P. Poyet, Impact of Information Technologies on the Design and Operation of Buildings. Proc. of the European Network of Building Research Institute / CEC Seminar on Construction Research Needs, October 31, (1990).
3. P. Poyet, Artificial Intelligence Software Engineering in Civil Engineering. Microcomputers in Civil Engineering 5 (3), (1990).
4. R. Cousin, Apport de la théorie des catégories à la représentation des connaissances. Thèse d'état de l'université de Paris VI, (1988).
5. P. Poyet, Integrated Access to Information Systems. Applied Artificial Intelligence 4 (3), 179-238 (1990).
6. P. Poyet and P. Haren, A.I. Modelling of Complex Systems. in: Modelling Techniques and Tools for Computer Evaluation, R. Puigjaner and D. Potier Editors, Plenum Publishing Company, London, 265-290 (1989).
7. P. Poyet and B. Delcambre, NOE: Expert System on Technical Inspection of Waterproofing on Flat Roofs. Proc. of Expert Systems in Civil Engineering, 58, Bergamo, 175-187 (1989).
8. Ph. Debras, P. Poyet, E. Brisson, expert systems and documentary databases integration, Proc. of Computers and Building Regulations, Espoo, Finland (1991).