TOOLS AND MODELS FOR THE ELECTRONIC DELIVERY OF BUILDING CODES AND STANDARDS

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The Internet and its hypertext application - the World Wide Web (WWW) - have opened a whole new media for the distribution of construction information, and more specifically of building codes and standards. The WWW is quickly becoming an alternative/complement to the electronic distribution of information using optical or magnetic disks. In this paper we investigate the strengths and weaknesses of the various representation formats and computerization tools in this domain; more specifically, we emphasize the idea that collaborative code and standards usage must be supported by on-line distribution of codes. The weaknesses and advantages of the applied technologies are reflected in W3BR, a WWW model for building regulations

WWW is an exciting new technology which provides entirely new uses for building codes. Its current state, however, requires serious compromises in the modeling, presentation and representation of building code information. In addition, specific models that have been developed can be integrated into an overall computer integrated construction schema.

Keywords: computerisation of building codes, hypertext, information systems, Internet, WWW

1. INTRODUCTION

"Building codes, design specifications and standards referenced by building regulatory documentation constitute one of the major communication and control mechanisms for the building industry" (Fenves *et al*, 1976). They are an important part of the construction industry and provide not only design and construction guidelines, but in many cases they establish norms for safety, dictate technology trends, limit dangerous procedures, and determine acceptable construction.

Building regulations[3] are confusing and intimidating to most novice or inexperienced users; frequent complaints of practitioners and students alike indicate that these documents are too complex and hard to follow (Fenves and Wright, 1977). As a result, months, if not years, of intensive exposure to building regulations are required to understand the inter-relationships of articles, and to interpret not only the words, but also the intent of the provisions.

Numerous information technologies have been employed to represent building regulations in the past, in an attempt to make these documents easier to use. Database, hypertext, and expert system implementations account for the majority of the existing research and commercial systems. The most recent technologies put to use in this area include wide area networking and groupware.

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3 In this paper the term "building regulations" will be used to mean either building codes or standards. "Computerization of building regulation" is a process of transforming a classical building regulation into an electronic format. "Standard processing" means electronic processing of building regulations.

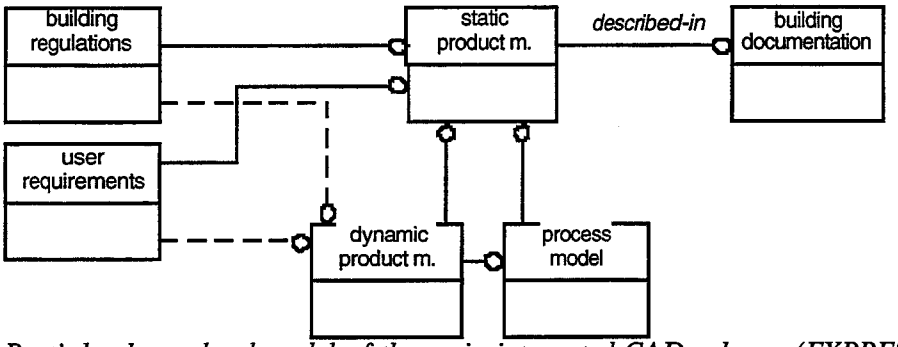

Fig. 1: Partial schema level model of the main integrated CAD schema (EXPRESS-G).

1.1 Problem statement

In the paper we propose delivering passive, hypertext representation of building regulations using the WWW. This may appear to some an obvious media for the delivery of text-based information; however, there are many problem areas that must be addressed that are specific to this combination of WWW representation/delivery:

- How does the Internet compare to existing distribution media ?
- What is specific (special etc.) about using the Internet for the delivery of regulations ?
- What effect will this media have on the computer representation, modeling, and presentation of the regulations?

2. W3BR SCOPE

W3BR (WWW for Building Regulations) is proposed as a WWW-specific model for building regulations. Its scope is compatibility with other components of integrated CAD, passive document representation, on-line building regulation delivery, and support of regulation usage life stage. W3BR is also open for extensions where the current scope is too limiting such as for active representation or full life cycle document support, and for translation to alternate technologies. These issues are addressed in the subsections below.

2.1 Regulations and integrated construction

Integrated CAD can be decomposed into five to six distinct modelling spaces (Fig. 1). The static product model contains the facts about the product; the process and dynamic product models contain information about the design process that lead to such a product (the who, when, how, or explored alternatives) and the design rationale (the why); and the building regulations and client requirements provide the criteria for evaluating the product and judging the design. In fact, the product must also conform to specific client requirements as well as to more general set of requirements formally defined in a set of standards, buildings codes, design guidelines, zoning by-laws, and other regulations. Building regulations are thus tightly related to the building product and to the product/process model on which engineers work.

2.2 Representation

Ideally, standards processing should actively restrict the set of possible solutions for a design problem to a subset conforming to the building regulations. This idealization im-

plies that the full semantics of the building regulations can be captured by a computer program and used actively to compare to the solution set provided by the designer (Dym *et al*, 1988). However, if the full semantics of the other engineering and client requirements could also be computerized, then a set of plausible solutions could be generated by a computer automatically. Comparison of the information content in all the regulations applying to a building with the requirements given to the designers reveals that the computerization of other requirements is the smaller problem. Yet this is the ambitious goal of the so-called active representation of standards! Artificial intelligence methods such as decision tables, rules, clauses, frames, and objects have already been used to represent regulations actively.

Although research into the active representation of building regulations has been quite extensive, only a few solutions have matured to a commercial level (Cronembold and Law, 1988; Sharpe *et* al, 1993). It appears that general solutions are not practical and that interpretation of building regulations in the majority of "industrial strength" programs is in the form of an embedded system where the provisions of a specific edition of a particular regulation are tightly bound with the application in question; for example, in proportioning of concrete beams, drawing, etc.

Passive representation of standards, on the other hand, implies a division between the meaning (semantics) of the regulations and the content: it requires parallel processing of the building regulations by both man and machine. Usually the machine is responsible for the search, delivery and reproduction of the regulations while the humans manages the interpretation. The only task which requires some knowledge about the contents of the building regulations is the search for relevant sections which apply to the given problem: some computer systems describe how this can be attained (Vanier, 1995). It appears that quite shallow knowledge about the actual content suffices in the passive alternative if the final representation and decision is provided by a human. Table 1 summarizes the features of active and passive computerized standard processing and the traditional systems.

Table 1. Types of standards processing

Question	Possible answers	Who answers (active rep.)	Who answers (passive rep.)	Traditional
Does this regulation apply?	Yes, No	computer	computer or human	human
Is my design conformant?	Yes, No, Don't know	computer	human	human

A much-used technology for passive representation of building regulations has been hypertext: - a non linear text with smart references to within itself and to other documents. The text may include other information representation like tables, pictures, sounds, and even video clips. The advantages of hypertext include fast access to textual information, quick prototyping of the user interface, elegant user interface design and multimedia presentation style (Casson and Stone, 1992; Vanier *et al*, 1993; Watson and Ward, 1992).

Yabuki and Law (1993) describe a "hyperdocument model for the documentation of design standards". In this model, there are connections to all the associated design standards through use of a browser interface. Their conclusions indicate that hypertext is a good environment for the document storage and retrieval for building regulations. They strongly suggest that any standard processing incorporate hypertext capabilities.

2.3 Delivery

Having identified that hypertext is a suitable technology for the delivery representation of building regulations: what are the options for its delivery, what are the problems, and what are the solutions?

The three main types of information delivery include: (1) "just-in-time" delivery systems such as telephone systems, consultant briefings, help desks, interactive information services, computer programs and e-mail, (2) "once-in-time" broadcasting of information such as radio, TV and US-NetNews, and (3) "just-in-case" delivery such as magazines, periodicals, books, tapes, CD-ROMs, and floppy disks, basically information that can be catalogued in libraries. The bandwidth available to individuals for the first type of service is small since they must share total available bandwidth and the resources. Until recently only very important, timely information justified distribution in this way. Since the just-in-case service has no time component, the bandwidth is close to infinity and most of the information (including the traditional building regulations) is distributed in this way.

In Table 2. CD-ROM is compared with on-line systems for the delivery of building regulations. Technology with a clear advantage in one category is displayed in **bold type.** We find that the key element which justifies the on-line electronic delivery of building regulations is the attachment of the kind of information which requires just-in-time delivery.

Table 2. Comparison of Internet and CD-ROM for building regulation delivery

Technology	*Internet*	*CD-ROM*
Speed	20 kbps, to increase dramatically	**300 kbps,** will increase slowly
Capacity	**unlimited**	600 Mbytes
Delivery Lag	**minutes**	typically up to 3 months
Annotations	**global, group, personal**	group, personal
Feedback to authors or experts	**click of a button**	different technology, mail or phone
Supports code writing and evolution	**yes**	no
Indexing	yes, will involve in community	yes, proprietary to software selected
Search	standard tools	proprietary tools
Client platform	any	platform specific
Server platform	any	-
Presentation	restricted to standard or lots of work	**non standard but anything is possible**

The information content of documents such as building regulations is not very large. The entire series of building codes of a moderately-regulated country fits comfortably on a single CD-ROM and is of the same order of magnitude as an hour of digitized hi-fi music. Even so, with lower bandwidths it is quite possible to deliver building regulations online and just-in-time. And if this is possible, what are the advantages of not only just-in-time distribution, but also of distribution where the content (regulations) is not distributed with the media itself (paper, disks)?. Delivery of CD-ROM-able information over the network has little advantage over the delivery of that same information using snail mail, that is, conventional post.

2.4 Building regulation life cycle

For the majority of their life cycle, building regulations appear to be static documents. A closer look, however, reveals that building regulations are very much alive. Three periods of life of building regulations can be observed:

(1) First is the phase of *writing the regulations* - a set of experts working on a document which should encapsulate their knowledge about natural phenomena and physics, -- with legislative precision. The research in standards processing has some 30 years of history yet it seems that the impact it has had on the process of *writing the regulations* and on their structure is very small. In fact, even though researchers have developed techniques to synthesize building regulations (Fenves *et al*, 1987), the large majority of building codes are written as they have been for the past centuries, or millennium.

(2) Next comes the phase of *regulation usage*. The building regulations are printed in many copies, are delivered to users and they start to live thousands of independent lives. That is, engineers write their own *annotations* to specific sections of the building

regulations; some agencies might write accompanying booklets with the *explanation* of the building regulations, and a few daring individuals might even *contact the authors* about an unclear statement or a special case not covered.

(3) Finally, the building regulations are *updated*, or even replaced by some other regulations. The frequency of changes to the building regulations, or for that matter to accompanying reference documents such as standards and guidelines, is measured in months or years. In addition, in some jurisdictions the updates have to be accepted by a regional legislature; thereby requiring many different editions of the same building regulations to be available in the same country at any one time.

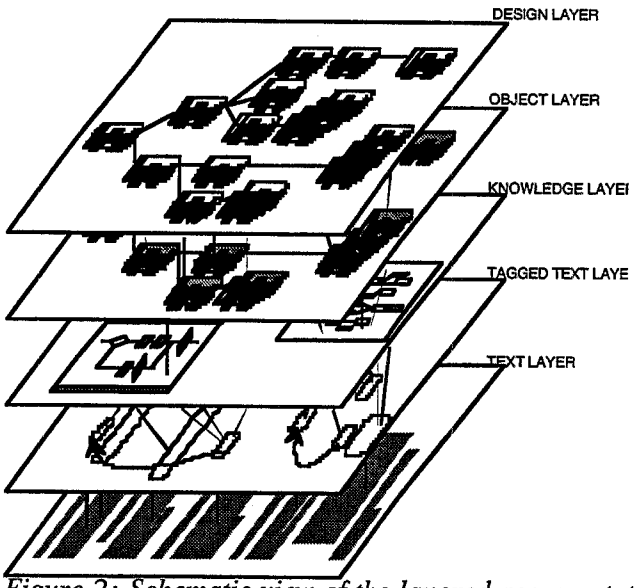

Figure 2: Schematic view of the layered representation of standards. Note the vertical lines that connect objects on different layers.

As can be clearly seen, the frequently-changing text of building regulations in the phase of creation as well as the numerous independent annotations and explanations represent the kind of information that can *only* be distributed on-line.

3. THE W3BR SCHEMA

The presented conceptual model is based on the layered representation of building regulations (Turk, 1991) that has been simplified for on-line implementation. This representation's main goal is to bridge the semantic gap between the regulation and the product. It attempts to do so with a set of layers spanning from the digital representation of the regulation, to the objects of the product model (Fig. 2). The W3BR model is in fact in the Tagged text layer.

In the model (Fig. 3) we divide the building regulation modeling space into the *regulation-document space* and the *regulation-content space*. The first defines a building regulation as a specialization of a document as defined in a schema like the CDMS (construction document management system) schema (Turk *et al*, 1994) (Fig. 3, shaded area). A building regulation is a document with all features of a document. In addition, it is issued by a certain organization (typically legislative or professional body) and it is valid for a period of time in a legislative entity (county, state, town ...). It also relates to other building regulations in four ways: (1) a building regulation may replace another building regulation, (2) it may add to another building regulation, (3) it may change another building regulation, or (4) it may reference another regulation in some other way. The building-regulation-to-building-regulation relation (RegulationRel in Fig. 3) may have a parameter that specifies parts of the building regulation to which it refers. A regulation may also relate to objects in a building product model. This feature is inherited from the general document and the CDMS schema. In addition, a building regulation may also contain a list of keywords classifying the topic of the regulation.

The second modeling space is the modeling of the *regulation-content* (Fig. 3, non-shaded area). Building regulations consist of parts (i.e. sections) which contain text, and non-text elements, such as tables, pictures and formulae. The non-text elements are normally positioned within text elements. The text elements have a title and some plain text; the plain text may include a cross reference. A unit of plain text is a paragraph which may be typed as a heading of a certain level or a normal paragraph. A cross reference can be explicit, such as a reference to a section or a non-text element, or implicit, such as to a variable or unit definition. Cross references point to a target which can be another regulation, a part of itself or a comment or a defined term.

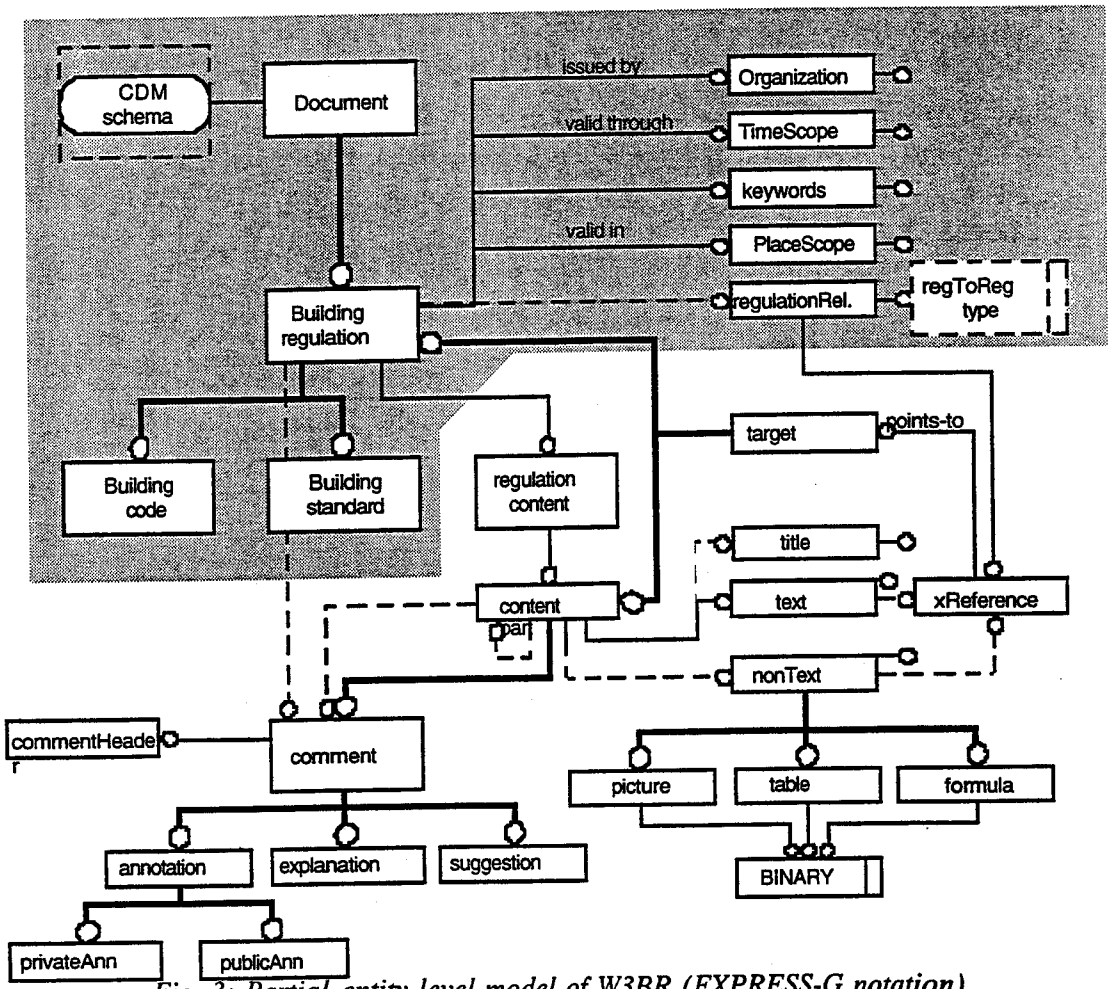

Fig. 3: Partial entity level model of W3BR (EXPRESS-G notation).

Whole regulations or any of their parts may be annotated. These comments may be private or public annotations, explanations or suggestions. They all have attributes of any other content part (*e.g.,* title, text, or cross references) but include a special header to identify the author of the comment. Comments may refer to other comments or to regulation parts. Explanations are other documents related to the building regulations. Only privileged users may add explanations to a building regulation. Finally, suggestions are structured discussion elements aimed at changing or questioning the building regulation contents with the regulation writer.

4. INTERNET AS AN INFRASTRUCTURE

Internet is the information highway of today. Slowly but surely construction companies are showing more and more interest in electronic communications as can be seen with the rapid increase in number of WWW home pages (*e.g.,* www.fagg.uni-lj.si, www.irc.nrc.ca, www.gatech.edu, www.aec.com and all the home pages that they reference).

With respect to the building regulations, many researchers in this field are realizing that the Internet may be the toolbox as well as the media.

4.1 Tools for representation and delivery

World Wide Web is an Internet service for networked delivery and the representation of hypertext. It was first implemented at the European Laboratory for Particle Physics (CERN) and gained considerable popularity once the graphical browser Mosaic was developed at the US National Center for Supercomputing Application (NCSA). WWW uses the Hypertext Markup Language (HTML) as a standard format for markup of documents, and employs the HyperText Transport Protocol (HTTP) as the communication protocol. Browsing within any specific document employs standard hypertext point-and-click links to documents anywhere on the Internet. Turk and Vanier (1995) describe in detail the basic Internet tools for the delivery and representation of building regulations. The Draft standard of HTML version 2.0 (Berners-Lee and Connolly, 1994) was used for the prototype WWW implementation of the Eurocode EC8. The main deficiency in version 2.0 is the fact that HTML is more of a typographical rendering than a markup language, such as the Standard Generalized Markup Language (SGML). Table 3 lists major deficiencies, possible work-arounds and impact that HTML 3.0 (early draft as of summer 1995) will have in this domain.

Table 3: HTML 2.0 vs. 3.0 and the representation of regulations.

Problem with HTML 2.0	Work-around in HTML 2.0	Problem status in HTML 3.0
No support for many national character sets;	Special adjustment of the WWW browser was needed specifying a Slovenian font as the default font on the expense of loosing some special characters.	Addressed.
No support for Greek symbols.	Greek symbols can be included as bitmaps. Aesthetics of the resulting document suffers, even more so when presenting the document on different resolutions where text is scaled and graphic is not.	Support expected.
No support for super- and subscripts.	Use of capital letters and different font sizes. This solution uses proprietary and non standard feature of one of the browsers which is not HTML standard.	Supported by some browsers now.
No support for mathematical expressions and formulae.	All formulae were successfully represented as bitmaps (Fig. 8).	Support expected.
No support for tables.	Tables are rendered as a pre-formatted text.	Supported by some browsers now.
No support for meta information and semantic tags (i.e. tagging text as unit definition or index entry).	There are only two ways to include any kind of additional information in HTML: to (1) hide it in HTML comments, or (2) into meta data with HTML's META tag.	Full SGML was proposed as an add-on WWW language.
Neither the links nor the bookmarks may be typed; it is difficult to implement one-to-many links.	Few link types could be rendered differently i.e. in italic or bold. One to many links could be implemented as menus.	Addressed.

4.2 Tools for searching and indexing

These tools enable the users to find a set of building regulations which apply to a given problem. The set must include all applicable regulations and should minimize the number of others. Within the framework of the model proposed, this kind of search can be based (1) on the meta data information and (2) on the full text of the regulation. The fastest and most time efficient is the search in the regulation's meta data. Such searches could be made more useful, if the meta-data would include a well defined set of keywords. Searching in full text takes more time, but the chances of missing a document relevant to a problem are much smaller. Htgrep, WAIS, SWISH and Glimpse search schemes were investigated. Except for the first scheme, all others are based on creating an inverted index of the full text. This works well for languages like English where each word has only one or two forms, as in "regulation" and "regulations". The Slovenian translation "pravilnik" has six forms for singular, six for plural (three or more) and another six when we discuss two regulations! This makes most of the on-line indexing tools quite useless for Slovenian language. In addition, Slovenian words include diacritical marks which are encoded as punctuation marks by most English-oriented software.

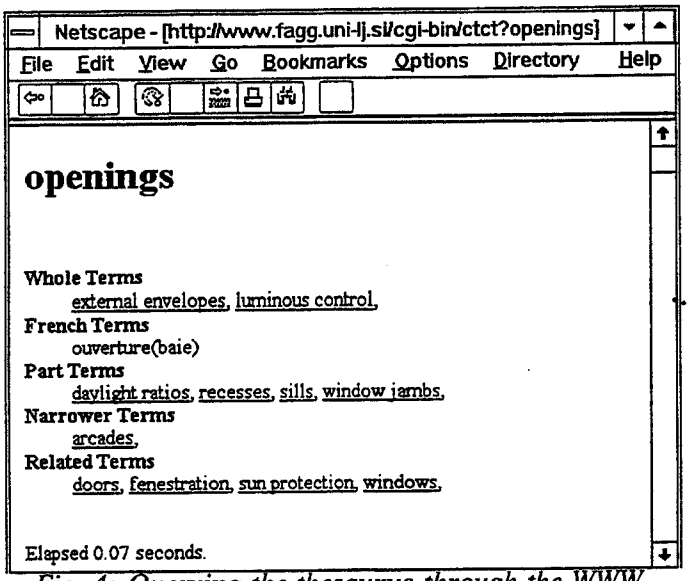

Fig. 4: Querying the thesaurus through the WWW.

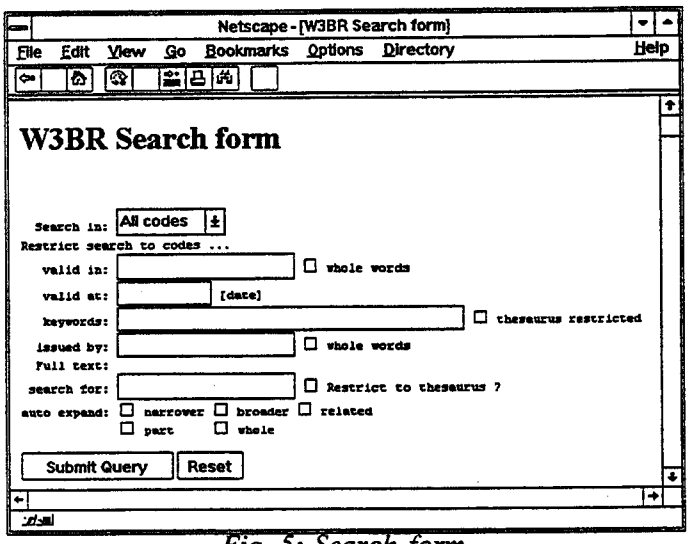

Fig. 5: Search form.

For these enumerated reasons we wrote a simple full text search engine that does a linear regular expression search through the full text of the regulation. Based on some testing, we estimate that an equivalent of 20 Eurocodes could be search in about 10 seconds using this method. We consider this sufficient since this is about the same as the delivery time of the full text of the code over local networks. Using linear regular expression search also enables the creation of friendlier presentation of search results as depicted in Fig. 9. Two other techniques were tried to make search results more efficient.

- *Weighted search* is a search where the success of the search is related to the context of the word found. For example if the word "window" appears in a section heading,

this regulation is more likely to be important to someone looking for "windows", than a regulation where "window" appears in normal text.

- *Expanded search* assists users looking for regulations on window who may also be interested in regulations that discuss openings. Information that windows is-kind-of opening can comes from supportive databases such as electronic thesauri.

4.3 Interfaces to thesauri data

Thesauri are a technique that can easily assist searches by providing controlled vocabulary for both the user (at search time) and the building regulation writer (at markup time). In any properly designed thesaurus there is a well-defined structure of *Descriptor Term, Broader Terms, Narrower Terms, Whole Terms, Part Terms, Preferential Terms, Use Term, General Terms, Related Terms, Associated Terms and Scope Notes.* The same holds true for electronic versions of thesauri (Vanier, 1992). In fact, these relationships provide a semantic network for the term under discussion.

In this prototype, a well-structured thesaurus (Vanier, 1992) was converted so that it could be queried as a HTML document. It can also be used to expand user's queries. Interactive WWW browser of the thesaurus has been developed (Fig. **Error! Bookmark not defined.**). The user is initially prompted with a search form as shown in Fig. **Error! Bookmark not defined.**. Next the user receives the thesaurus expanded form or a warning that his search term is not part of the controlled vocabulary. The form can be further edited to delete any unnecessary expansions. This query is finally submitted (either explicitly or transparently) to the system. Integral to this search engine is the preprocessing of the building regulations using the same thesaurus terms. The preprocessing involves marking up each paragraph in an HTML version of the building regulation (as well as terms used in parent headings) with all related thesaurus terms. For example, if a paragraph employs the term "window", and the parent heading uses the term "housing", this paragraph would be indexed with terms such as "residential construction" and "fenestration". Therefore any searcher using any of these terms would be brought successfully to the appropriate paragraphs. Although this idea has not been fully implemented in this project, the concept has proven successful in a closely-related project involving the MiniCode Generator (Vanier, 1995).

4.4 Annotation systems

Annotation systems must allow the users to add comments and notes to the regulation they use or study. These additions must become an integral part of the regulation delivery system and of the application that is used.

Information transfer on the WWW is primarily a one-way street from the server to the client. (i.e. a regulation is distributed from the server host to the client's PC). Transfer in the other direction is an exception to this rule, with the exception that queries can be sent from the client to the server. Some other Internet services specialize in communication with balanced information flows, most notably e-mail capabilities within WWW clients, US Net News, the interactive Internet Relay Chat and other conferencing systems but they are not tightly integrated with the WWW. Some browsers (i.e. Mosaic) implemented the so-called annotation facilities where users can annotate a particular page with comments of their own. Similarly, a group of users could post and share annotations. Unfortunately, this feature is not standard and numerous other solutions to support collaboration have been developed. In the prototype we used Hyper News which "is a cross between the hypermedia of WWW and Usenet News. The basic idea is to allow readers to respond to any articles or responses they read in the HyperNews web. The articles support moderated organization of information, while the responses support non-moderated discussion about the information". (LaLiberte, 1995). The system uses WWW forms as modes of input

and have modest technical requirements towards the WWW server. They are compatible with all HTML 2.0 conformant WWW clients.

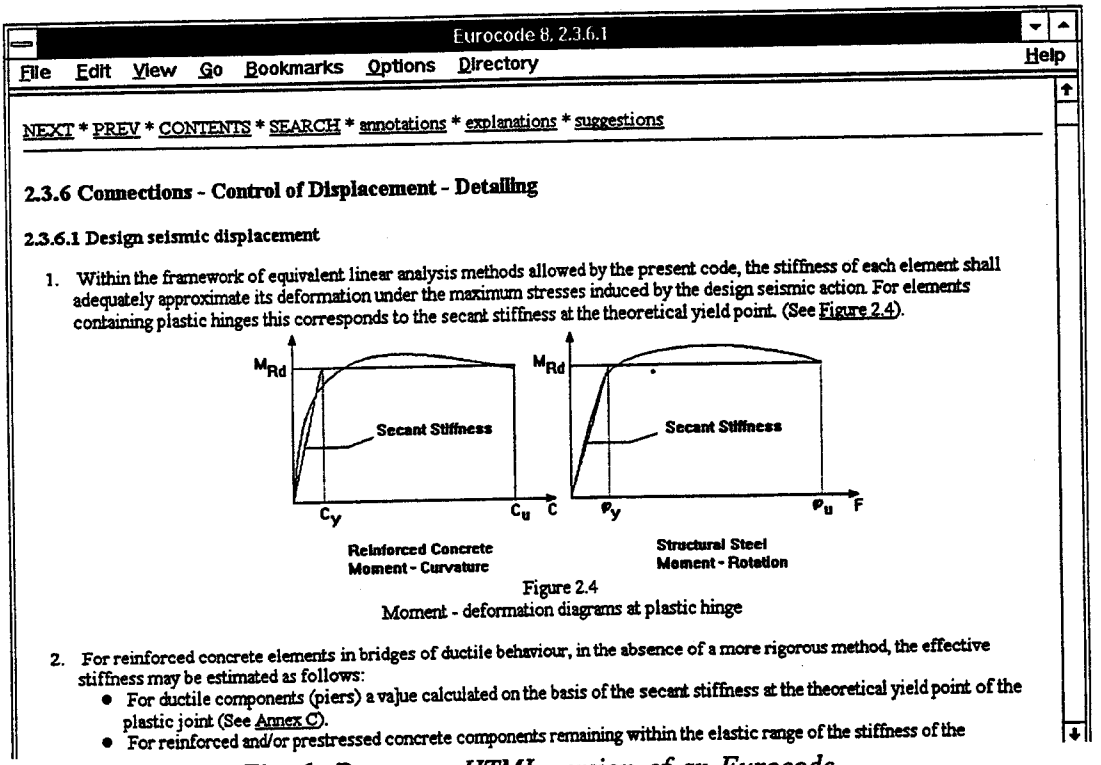

Fig. 6: Prototype HTML version of an Eurocode.

5. CONCLUSIONS

Information networks like Internet permit the just-in-time delivery of currently valid building codes. The key advantage of using these networks compared to other electronic distribution channels is that they enable sharing of human resources "connected" to Internet and that they create virtual teams clustered around documents and codes.

Internet delivery is slower and less flexible than CD-ROM versions but the user interface and the representation are standardized. The Internet capacity is unlimited and there is no time lag for the delivery of documents.

Internet's hypertext representation language HTML is weak for the representation of building regulations. Currently it lacks refined support of tables, indexes, formulae but more importantly, support of general mark-up features. We don't consider HTML to be a suitable electronic format of the codes; however, other languages (like SGML) could be used as the neutral electronic representation and HTML should be a result of a (possibly context dependent) translation process out of SGML. There is no doubt that such tools will be readily available on the Internet in the not-to-distant future.

On the Internet we have found most key tools needed to support the computerization and to implement a prototype system; most of them were free and many included source code for easy customization.

The future will definitively bring us the delivery of information including the building regulations over the information highway. The WWW and its related technologies are in their infancy. Products like HTML 3.0, Hot Java and WebSpace will influence the upcoming implementations. Encouraged by this work, an on-line standards library is be-

coming a part of the Slovenian technical information system for construction industry (TIGRA). Future research will move towards an active representation of regulations in an agent based networked environment

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