Categorisation of design information in terms of design process and product specifications for a standard for computer representation of specifications

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Abstract

Design information is categorized in this paper in terms of both the design process and product specifications, as a basis for computer representation of specifications. This requires improved definition of standard specification and product structure, as well as information handling in design checks. A computer representation of specifications for interactive design use and data exchange is described using the conceptual framework outlined. It is based on symbolic graphical representation of specifications linked to screen windows containing text and computations. Some requirements of a standard for computer representation of specifications are outlined.

Introduction

Specifications are represented using many different types of symbol. Until recently, software for one type of data, such as word processing, hypertext, graphics, spreadsheet or a DBMS, took up much of the power of a desktop computer. Now these different methods of handling data can be run concurrently and, increasingly, software for one type of data is developed to incorporate features found in other packages. DBMS get word processing facilities and can interface to spreadsheets. Graphics packages provide notepad facilities. Text processing contains computations linked to graph displays.

This paper considers computer integration and interactive use of different types of data for computer handling of specifications, in particular for graphics, computation and text. Information is categorized with respect to both design process and standard specifications adopted for a product. This requires definition of

* types of specification
* data types in specifications and their representation
* related data processors
* task control to facilitate interactive assembly of specifications.

Novel data handling techniques made spreadsheet processing possible; the button was devised to provide hypertext links and layers were devised to facilitate graphics processing. Interactive computer techniques for handling different symbols for specification assembly need to be standardized.

To provide a basis for object-orientated representation and processing of different types of specification information, definition of standard specification and product structure should be sophisticated enough to encompass

* classification of the increasing number of standards

and for interactive decision-making

* representation of functional or performance specifications
* access to arguments used to justify design decisions
* exchange of data between software.

This paper considers appropriate definitions.

Specification information has been classified into two aspects, normative and informative. Use of decision logic tables, organisation networks and argument trees to formulate, analyse and synthesise design information, developed into SASE, is essentially restricted to normative information [SASE87]. Limitations of expert systems are being investigated using links to interactive hypertext perusal of standards information [Stone91]. A 'unified model' of standards information is sought, possibly based on extensions of SGML developed for text processing [Reed91]. SGML mark-up

* separates logical elements of a document
* enables processing functions to be performed on those elements [ISO86]

for which, types of information in specifications and associated processes need defining. What processes should specification information be linked to?

In this context, STEP product definition concepts issued for comment offer limited assistance. STEP seeks a 'neutral format' of product definition entities to expedite data exchange [STEP91a & STEP91b]. General resources are limited to material, presentation and shape issues, such as tolerances and features. Various additional Schemas are intended to handle information about product changes, approval, security, version, category, lifecycle and information of an administrative type. Application Protocols are proposed to define additional activity models, but are intended to use STEP resources only. An Application Protocol is intended to to define specific functionality, which includes information needs of an activity, the basis for data exchange and conformance tests. A Product Definition may reference other information through an External Specification Schema.

Currently, the types of information being standardized within STEP are limited. Of the different categories of information required to define a specification, discussed below, only shape issues are being standardised. Indeed, the concept of specification is not defined in relation to product definition. A standard for the representation of specifications will be needed to produce Applications Protocols which can exchange the different types of data making up a specification.

Proposals in this paper stem from research into interactive computer display of design information. A hierarchical display of all parameters, their values and results of a global check on specifications selected from a library data base for a design has been described [Toms85]. Design information was categorized in terms of specifications. This involved

* improved definition of a design check
* not handling a specification as a rule
* identification of factors limiting engineering judgement.

Software enabled a specification to be selected interactively and associated with a structural member. Scrutiny of check results on selected specifications followed a routine 'big bang' where all generated data was retained. Explanation of available specifications was available as source, limits, logic, analysis method and failure messages. Subsequently, inadequate definitions in a guide to the drafting of British Standards have been discussed [Toms88]. Recently, a symbolic graphical computer representation of design specifications has been devised.

Firstly, to categorized design information, this paper considers characteristics of a product, standard specification and structure in terms of the design rpocess and product consumption. Secondly, a prototype computer representation of specification information to facilitate interactive use and data exchange is described. Representation and display of specifications in a library and interactive selection into a design are considered. Software access is required, maybe to generate or alter design specifications, check for consistency or carry out design checks and display results. This might involve the use of knowledge-bases about design techniques and "intelligent" processes, which are not considered here. Thirdly, some requirements of a standard for the computer representation are outlined.

1 Categorizing design information

Product described in terms of specifications

As the outcome of one process, a product is incorporated into subsequent processes (for example, the erection and use of a building) and, as such, provides required specifications (figure 1). A product is purchased for use in an industrial process to satisfy environmental requirements. There are two aspects to consumption of a product:

* storage, transportation and incorporation into a process, for which a product can be regarded as an arrangement of materials, as mass
* utilisation in a process as a repository of required specifications.

Specifications constitute both the input and output of a design process. As the output of one decision-making process, a specification is used for the input to a following process. A product specification is based on specifications adopted as standards for the project (see figure 2). When a product is consumed, either it determines environmental requirements or provides design concept specifications for a following process, depending on whether it is being stored, transported and incorporated or utilised as part of another product. A satisfactory design contains an arrangement of material which meets design concept specifications chosen to fulfill environmental requirements for an acceptable cost.

Design adequacy can be discussed in terms of conformance to specification. Decisions about the purchase or use of a product are based on arguments demonstrating that product specifications will meet environmental requirements, defined to include user requirements. Justification for the material configuration of the product and probable performance is based on information found in specifications of previous practice or tests.

To relate all design information and processing into a coherent framework based on specifications requires clear definition and use of terms describing both design objective and process.

Standard specification as an understanding

It will be generally accepted that a standard specification provides an'understanding' about the production or use of a product; between manufacturers seeking purchasers; by designers to control contractors; by regulatory authorities to constrain product form. But what is the scope of the 'understanding' which has to be represented in the computer? For software which is required to simply carry out computations after decisions have been taken, a narrow prescriptive meaning would suffice. However, for software intending to assist in decision-making, a meaning must encompass all aspects of specification information to be handled.
BSO part 3 clause 5.1.1 defines a specification to be

> 'a detailed set of requirements to be satisfied by a product, material, process or system' [BS091].

A process specification describes steps of product manufacture (clause 7.2.1), where the outcome of a step presumably is a product. The meaning of system is not defined. 'Material, process or system' are products, but are defined synonymously with 'product'. None of the terms adequately describes a building as a product type and an improved definition has been proposed, as follows.

A building structure, invariably made up of many components, is devised to contain an activities, or work, environment (figure 3). A design specification must encompass performance requirements for two compatible processes: firstly, production of structural components and secondly, construction and maintenance of the required work or activities environment. A system or process can be described in similar terms. A such, a building has been described as a product comprising compatible processes [Toms88]. Using this conceptualisation a specification can be defined as

'a detailed set of requirements to be satisified by a product, comprising material, space or compatible processes'.

Each feature of a product design, say of a structural component or assembly, can be described in terms of a hierarchy of specifications. Every concept used ina specification, from symbols for mass, dimension and time to mathematical computation is either defined therein, or referenced, perhaps implicitly, to a specification in another document. In practice, specification of many frequently used concepts is assumed without reference, though 'wording should enable conformity ... to be verified equally by first party (supplier), second party (purchaser) or independent third party certifier' (BS0 part 3 clause 5.7.1). What are the characteristics of specification information that communicate this understanding, to

* adequately represent the description of a design product
* justify a chosen product configuration?

Structure and structural form

Structure is usually described in terms of geometry, material and attributes. For a definition of structure in terms of standard specifications, as defined above, the distinction between structure and structural form has been considered [Toms91]. Thus

* structure is defined by structural forms selected to suit environmental requirement specifications of both the surrounding and internal spaces.

For example resisting an external wind or sustaining mass for intended internal activities. Structural form as design concept specifications can be described in terms of environmental characterisitcs created by the structure, as a compatible process. Thus, a wall deflects wind mass as a vertical plane to protect a space; abeam sustains masses between points in a space.

Design representation

Symbols used to represent structure may be classified with respect to two aspects of the decision-making process:

* conceptual decisions, selection of preferred specifications
* detail specification of material.

Design information in these two categories includes:

Concepts:

Working environment: Environmental requirement specifications, such as boundaries to space or area, openings, deflection limits and activities in the space, as loads etc.

Structure: Design concept specifications, beam, slab, etc.

Detail:

Materials: Detail geometric and attribute description of material which satifies selected specifications.

Environmental requirements and design concept information for the product are derived from standard specifications, and are usually represented with text, sketches and calculations. Product detail is usually represented on drawings using geometric symbols and attributes referencing textual documents and specifications of other incorporated products. A computer representation of specifications is described below for handling design information in these terms.

The design process: justifying a design

What categories of information are needed to justify a design and how are they represented?

Selected specifications are often represented on a design concept sketch. the sketch in Figure 4 represents a set of specifications comprising a proposed product specification. For assumed environmental requirements the sketch shows the type and extent of selected specifications. Beam, deck, stanchion and footing specifications are declared for a bridge structure. Proposed material type is shown, but material dimensions are not. Sufficient dimensions are shown to relate the location of propsed specifications with respect to ground profile.

After selection of material type and dimensions of components, the adequacy of a design cocnept has to be established. A design check is carried out to determine whether the material configuration satisfies chosen specifications, maybe one or a set of design concept specifications taken together. Figure 5 shows the sequence of tasks undertaken to establish whether a design configuration satisfies a standard specification. Design information in the five categories shown on the right hand side of the figure are generated from information in

* four categories of an environmental requirement, and
* five categories of a design concept standard.

All these categories of information need to be represented by the computer to facilitate interactive design and access by other software.

To use a standard, it is necessary to declare the extent of application of the specification to the design configuration by choosing suitable parameter values. For example, for a column in a frame, a dimension must be chosen for a check on load carrying capacity for a frame analysis. For a stability check an effective length must be chosen. Invariably, parameter values chosen for checking in the standard computations are different to anticipated (and final) material dimensions, see figure 6. Modelling of a design to a standard is a key design task. Typically, diagrams showing parameters for the extent of application of a specification are represented in calculations, in relation to proposed material dimensions. Detail drawings show material type, arrangement and dimensions only.

Parameter values are selected, or derived, using guidance form a standard. The following limitations are inherent in design checks

* a standard specification is applicable to a limited range of configurations and material types
* the required degree of precision necessary for parameters used in checks is not always readily understood
* analysis routines invariably involve simplifications alternative specifications are often available for assessing performance and may yield different results [Toms85].

A standard specification presents only one interpretation of test results or experience, which a designer may not consider is wholely appropriate to a particular design. The same standard used for a design check by different designers may yield different results, depending on the parameter values selected from the modelled design configurations.

The use of selected specifications is justified through comparison of results of design checks to standard specifications adopted. In particular, performance indicators for the standard have to be considered with respect to the scope of selected environmental requirements and design concept standards, and the appropriateness of the modelled design configuration. Hierarchical display of design information in increasing detail assists interactive assessment [Toms85].

Are standards rules?

To what extent are standards rules? To carry out a design check using a specification requires adherence to the sequence of design check tasks shown in figure 5. But the specification information itself is not rules, it is a record of tests or practice. The scope of a specification must be adhered to, thus a specification for the design of a concrete beam cannot be used for a timber beam. However, appropriate selection of a specification and conformity to a sequence of design steps, there being no other way to generate the design information, does not make interpretation of the contents into rules.

A design is always chosen and modelled to conform to a standard. Only where a design situation is identical to that used as the basis of a standard would no modelling be required. The location of a building component is always unique, requiring a check that the environment (maybe temperature, humidity or wind load) is not outwith the scope of the specification. Even with repeated use of a design, a check is made that the chosen standard is appropriate to the selected material configuration. A designer models building design configuration to conform sufficiently, rarely exactly, to an existing specification. That is the basis of innovation.

The scope of a specification may be so narrow that, in following a sequence of decision-making tasks, the contents appears to be prescriptive. A method of testing appears to be prescriptive, though its applicability must be checked at every stage. Logical aids, such as decision tables, may be used to ensure all aspects of a specification are considered. Though dependency networks may be devised to show links between parameters, this does not make a specification content into rules. Possible applications of a specification may be restricted to permit automation of design work. For repetitive design work, a design aid may take the designer routinely through design steps to generate an adequate design, with minimal consideration of the suitability of a standard. A standard devised to ensure conformity of action can be represented as a logical 'black box', leaving decisions about applicability to a design to be taken elsewhere.

Prescriptive provisions have been included in standards to reduce the need for design judgement. Kerensky, introducing a discussion of a report proposing a common basis for safety factors in structural design codes 'to achieve optimum level of safety at minimum cost' stated

> 'It is unnecessary for the code user to understand the somewhat complex mathematics and concepts behind the methods proposed. I do think laymen should take the mathematics on trust' [CIRIA77].

UK structural engineers opted to retain a permissble stress reinforced concrete design code, in spite of British Standards intention to supercede it with load factor codes [ISTRE90].

Increasing use of functional specifications and the need for environmental assessment for which information has to be understood, discourages the use of prescriptive standards. For computerization, the contents of a standard should not be regarded as rules, rather

* the applicability of a standard to a design is based on judgement
* a routine sequence of tasks is needed as a design check to undertake this assessment (figure 5).

Classification of design information

The approach adopted here differs from other recent proposals for classification of structural design information, which does not consider the role of the information in the design process. Thus, 'primitive objects' have been classified in terms of form, function and behaviour [Howard92]. An example links information as 'primitives' for spatial form, topological form, materials, functions, geometric properties and behviours into a 'composite' class for beams. Form, function and behaviour are used to classify information as aspects of a product only.

In this paper, design information is classified in terms of its role in both the design process (figure 5) and product specification. A proposed product (for example, a structural component) is represented in terms of subsequent processes, both transition and utilisation, intended to form a subsequent product (a building), as discussed above.

Types of information

The use of a specification in a design process may be classified in two respects:

* use in design check
* role in the representation of a design product.

Specifications for adoption are found in standard specifications and codes of practice.

(i) Use of a specification in a design check
The contents of a specification may be used for one or more of the design check tasks shown in figure 5. Thus, a specification may only contain a method for assessing behaviour, or be a glossary of terms for definition of parameters.

(ii) Role in design representation
A specification is used to define one of three aspects of a product: environmental requirement, design concept or material configuration which are declared in relation to each other, using a fourth type of specification, a spatial grid.

* A grid defines three-dimensional space, usually using labelled lines.
* Environmental requirements are specified prior to consideration of an appropriate design concept. They concern the functional performance of space, both in terms of composition (size, etc) and content (activities contained). Values adopted for an environmental requirement are the outcome of a decision-making process based on previous practice or tests. This may involve selection of appropriate data from tables or use of computations from a code of practice or specification, which involves both comparison and computation.
* A design concept is selected to sustain environmental requirements and a product configuration. To sustain an activity, structural integrity of a product and its compatability with adjacent products is required. At minimum, a design requires checks on a compatability and integrity specification as well as cost [Toms85].
* A product material configuration is specified to serve two functions. Firstly, it is required for construction or manufacture of the product. Secondly, to enable a purchaser to decide on possible utilisation and, as such it may be described in a catalogue. A purchaser (or designer as agent) decides on an appropriate method of assessing performance in service for the chosen process within which the product is to be used.

Related specifications

Interactive design involves

* association of specifications with a selected design
* design checks on slected specifications.

From a decision-making point of view specifications are associated in three respects: spacially, nested and sets (figure 7). These associations are often declared with design calculations.

(i) Specifications are related to each other spacially, their location and extent being reference to a grid. Symbols showing design concept specifications are sketched in figure 4 (a grid is implied by the ground profile). Likewise, the layout of environmental requirements, such as loads or clear spaces, can be shown using symbols. A product drawing shows the boundaries of materials using geometric entities specified spatially.

(ii) Design concepts or environmental requirements specifications are defined in terms of other concepts, referenced within as nested specifications. Detail specifications of structural systems contain nested specifications for components. It is a function of a specification to reference standard specifications. Only new aspects need be described, old ones can be referenced.

(iii) For the purpose of a design check on a building product, comprising compatible processes, sets of specifications may need to be assembled for particular checks. Thus an integrity check on a steel frame requires information from specifications for selected columns and beams to be combined into a model for analysis. For a single structural component, different specifications intended to act together may need to be considered as a set.

Thus a product specification, or standard, can be regarded as being made up of

* sets of nested specifications in particular locations.

Each specification is a repository of information for explanation and decision-making, as opposed to instruction.

* For a building product, sets of specifications are assembled into a specification
* For a standard, sets of specifications assemble into a standard specification for material and spaces, or a code of practice (as guidelines) for a product comprising compatible processes.

Standard specification

The classification of types of standard in ISO Guide 2 is not a useful basis for computerisation of design information [ISO86]. It describes four types of provision, using appropriate terminology: requirements 'shall', recommendations 'should', instructions 'imperative mood', descriptions 'present tense'. Types of standard can be identified with respect to this terminology. Thus, British Standard specifications are used where 'all applicable requirements ... have to be satisified if compliance is to be claimed' (BS0 part 3 clause 2.1.2) [BS091]. Codes of practice 'recommend good accepted practice' (clause 9.1).

In practice, however, both standard 'specifications' and 'codes of practice' contain specification information for adoption, as defined above. Choice of standards is the responsibility of the designer who determines the extent of compliance (figure 6). Distinguishing between types of standard on the basis of compulsiveness appears to stem from a historical preference for prescriptive standards.

In practice, the contents of particular types of BS have not complied with preferred use of terminology. Standards of a declared type contain a mixture of terminologies in provisions. Recent revision of BS0 indicates that the word 'may' can be used to indicate 'a course of action permissible within the limits of the standard' and the word 'can' may be used in 'statements of possibility and capability' (clause 4.5). Strict definition and control of terminology is proving difficult. It is clear that when parsing for a standard for computerization, terminology which is supposed to conform to a type of standard cannot be relied upon for useful categorization. What then distinguishes types of standard as specification, code of practice, glossary, method, etc?

Using concepts outlined above, a BS 'specification' can be considered to be applicable to a product which simply comprises definable material and/or space (a brick) and, as such, can state limiting criteria. Codes of practice give recommendations about standard environmental requirements and design concepts for the design of a product comprising compatible processes (foundations or steelwork frame). A code cannot give definitive design guidance for a product made of many components of unknown configuration, but 'may pave the way to eventual formulation of a specification' (clause 2.1.4). All other design information is considered here to be related to standards of these two types. Methods, glossaries and schedules can be handled as specifications which nest within parent specifications. From this point of view any informative information can be related to particular specification data types (figure 6).

A standard has been described as consisting of two "conventionally disjointed" domains of information: formal texts and associated argumentation [Stone91]. ISO Guide 2 distinguishes normative and informative information. Apart from being selected as a standard, and being presented concisely and unambigously, are the two sorts of information actually different? Both describe aspects of specifications and could be categorized and represented in a similar manner, to be made available by the computer for pasting into a design specification.

All design information, including that found in manufacturers catalogues, could be held on the computer in terms of the specification data type (figure 5) to which it relates. How then would certain information be identified as normative? Its title (indicating adoption by standardizing body) and screen display (say colour of text or window border) could indicate as much. Information and references would be available for interpretation by the designer, rather than instruction.

Confusion as to the purpose and content of clauses leads to conflicting presentation. For example, BS5950 section 2.1.2 is headed 'Methods of design' but concerns assumptions made about connection behaviour (simple, semi-rigid and rigid) for the purpose of analysing load carrying capacity. Strictly, the section should be headed 'Analysing behaviour of connections under load', as guidance is not given on material selection. When parsing clauses for incorporation into the computer headings and terminology cannot be relied upon to identify the type of information contained in provisions. Much of the mark-up of standards for computerization will have to be done manually.

Representation of standards

For computerisation, a standard should be regarded as a repository of information for explanation and decision-making, not instruction, whose use has probable results within limits declared. Information is needed in each of the categories shown under standard in figure 5. It must be possible to scrutinize any category of information concurrently with any other. Different types of symbol are used for representation, a new specification may contain new forms of representation.

A standard specification is typically made up of many nested specifications. Thus, BS3921 the standard specification for clay bricks, a material product, contains six nested specifications [BS3921]. These are titled durability, effluorescence, compressive strength, water absorption, dimensional conformity and visual acceptance (figure 8).

BS5950 is a code of practice for the design of steelwork, which is a product comprising compatible processes [BS5950]. It contains both environmental requirement and design concept specifications, though predominantly the latter. Deflection criteria and the need for fire resistance are two example of environmental requirement. Load requirements is an example of a nested specification which references other documents.

One clause may serve several nested specifications. In BS3921 one scope (and foreword and introduction) introduces six specifications. Definitions of parameters are collected together for all subsidiary nested specifications. Information of one type is contained in more than one clause, thus foreword, introduction and scope, contain scope information. But only the scope is normative (it defines 'the function of the standard'), foreword and introduction are 'preliminary informative' clauses (BSO part 3 clause 3.1.1).

Each standard has a unique title. For a standard specification or code of practice made up of, or referencing, other nested specifications each subsidiary specification should be given its own title (eg clay brick or clay brick effluorescence). This permits computer retrieval by keyword. Each concept in a standard is either define therein or referenced to another standard. This reference may be implicit, for example, for mass, temperature and length.

The use of a standard involves the declaration of a location and extent of application, and, by reference, other specifications to which it is nested. It may be declared to be in one or more sets of specifications for particular checks. Computer handling of specifications requires suitable representation of the manner in which a specification, or a set of specifications, is applied as a standard to a design.

2 A computer representation of specifications

A computer 'sketchpad' has been devised for handling design information in terms of specifications. It provides for

* selection and graphical display of symbolic representation of environmental requirement, design concept standards and material configuration
* a library of specification information
* links between these specifications
* display of associated textual and computational design information in windows adjacent to the symbols
* task control to assemble specifications
* interactive access to any design information and concurrent display of different information
* availability of design information to other processes.

Symbolic graphical representation of specifications linked to spreadsheet and DBMS forms has been used to implement these objectives (figures 10,11 and 12).

Use of symbols

Symbolic representation showing product type and location is used in heating and ventilating, electrical and architectural graphical design software. In the UK industrial support for the production of "generic drawings of types of building product, supported by essential data including manufacturers names" as "catalogues of attribute data" has been sought [NEDO91]. Structural engineering frame analysis software typically uses symbols to represent both loads, as an environmental requirement, and a chosen frame model for analysis of behaviour.
Symbols are used here to locate, name and relate specifications in space, and are linked to associated data held elsewhere in appropriate formats (text, tables, computations). Their use is novel in several respects

* each specification is associated with a graphical symbolic
* spacial relations are declared with respect to a grid
* dimensions of each symbol represent key design check parameter dimensions, permitting graphical scrutiny of key design assumptions
* specification types are formally separated into different layers which may be viewed together
* each symbol is linked to associated specification information.

Environmental requirement and design concept specifications may be represented graphically on the screen to show the extent of application of a specification. These symbols may be viewed overlaying each other and/or material configuration. Several layers may be used for each type of specification. Thus, symbols for clear spaces may be declared separately from other environmental requirements.

Use of proprietary software

Proprietary software was used to prototype data handling techniques with the minimum of programming effort. The software enabled requirements for specification representation to be investigated relatively easily. The functionality of three packages was combined, graphics, spreadsheet and data base software, linked using their functions plus 'C' programs where necessary. Autocad graphics, Lotus 123 spreadsheet and Oracle relational data base were used on a Unix Sun 3/60 workstation with large screen and windows. Facilities available with minimal programming effort include

* user definable functions and menus

* access to data base contents
* other applications programs may be called.

The software was selected to represent the different types of specification information in figure 5, as shown in figure 9.

Each process was run in a window and could be 'parked' using specially devised macros which scanned a file for an interrupt message and data from another package, as a signal to transfer task control. Thus graphics data input interactively by the designer can be transferred to the spreadsheet or DBMS, as discussed below. Additional functions to those provided with the software were devised using Autolisp, Lotus 123 macros, Oracle triggers and 'C' programs. Since completion of the prototype interfacing facilities in these packages has been enhanced by the developers (Autocad in particular).

A spreadsheet was used as it offered interactive input and display of calculations with systemmatic computation, and open access to all data. Spreadsheet macros can automatically dump data into the relational data base for other programs to access. Devising a basis for integrating sophisticated design office spreadsheets (which were discussed with designers during the project) was a research interest. Specially written software to handle specifications could incorporate many spreadsheet functions, with enhancement.

Oracle provides for more sophisticated data entry than the limited attribute facility in Autocad. Tables may contain more fields, be linked together and be accessed from an Oracle menu. Data can be deleted or altered from other programs. Display of design information in different forms can be accessed through Oracle menus, in the hierarchical manner referred to above [Toms85].

Integrating information processing with a graphical menu

Information related to a specification may be accessed through an appropriate graphics layer to display environmental requirements, design concept or material detail. A graphics menu control (using Autolisp) enables the user to

* switch between layers and concurrent display
* declare or alter concept specifications and the drawing of product detail.

Graphical attributes trigger, and menu commands call other processes, which return themselves to the graphics menu on completion.

A library of specification data comprises the data bases and files associated with the three software packages used to represent the different types of specification information. Related information in the different data bases is linked invisibly to the user. Data associated with a specification symbol is displayed in its appropriate window without the user being concerned about data storage techniques.

Specification symbols representation

Symbols devised for environmental requirement and design concept specifications are shown in figures 10 and 11. They are held as part of a library of specification information which includes spreadsheet and data base forms. They are shown in plan selected for a design with respect to a grid, and may be viewed in three dimensions. Symbol shapes have been chosen to portray the extent of key parameters associated with the specification. Each symbol representing a specification may be added to a design and be redisplayed or erased when picked off with a mouse. Material configuration represented with geometric entities and attributes is shown in figure 12. Attributes on the drawing may be linked to other information dsiplay, such as schedules.

Environmental requirement symbols for point, line and area loads are shown in figure 10, overlaying the detail layer. A load symbol may be located, and, as attributes in response to

Autolisp requests, a label for the load and the structural element onto which it acts. For a point load, location is picked off, for line and area geometric bounds are requested. Having declared attributes, a data base form for the load type is automatically displayed and filled with the graphical information (coordinates of load symbol, label and structural element). Further load information may then be input into additional fields in the form (such as load values). Symbols for other environmental requirements, such as clear space, are held on other layers.

Design concept symbols for three reinforced concrete structural design specification, beam, column and slab, are shown in figure 11. For a beam, the symbol has been devised to enable input of span and orientation of the beam for design check purposes. Design span, usually different from material dimensions, is picked off with the mouse, a beam identification and a selected design standard declared as attributes to the symbol, using an Autocad dialogue box (not shown). The standard declared is used to select appropriate spreadsheets containing design checks. Having declared the attributes, a spreadsheet is displayed automatically in an adjacent window and graphical data transferred automatically (attributes and coordinates). Additional data for material properties and dimensions assumed for design check purposes may then be entered, specific design checks selected from the spreadsheet menu and carried out, results being saved to the data base. Slab and column specifications are represented in a similar fashion. Location of the end of a three-dimensional column symbol determines the height for design check purposes. Design concept symbols for building services, similarly linked to other processes, may be held on other layers.

Having entered several design concept specifications it may be necessary to carry out a design check using from each specification. Thus, software could be called to declare a set of specifications and carry out a load analysis on a structural frame drawn on another graphics layer. Such links have not been completed.

Concurrent display of text

Specification clauses as texts may be requested and viewed as data base tables of text, at any time, throught the menus of any of the three packages (see spec_explain in window in figure 12). This could be developed into a hypertext facility, for both input and display of information.

3 Some requirements of a standard for computer specification representation

Categorization of information

Standard specification and product structure should be defined, and design information categorized, without reference to type of product in terms of both the

* processing of design checks, and
* the process of product transition and utilisation.

This requires definition of

* types of specification
* data types in specifications and their representation
* related computer data processes
* requirements for interactive assembly of specifications.

In addition, for a document, categorization of information should be defined in terms of

* document functionality, title, contents, index, etc.

A standard for the representation of specifications should include definition of symbols and required functionality of related processes (such as screen display). Many computational and display requirements can be described in terms of facilities found in graphics packages, word processors, hypertext, keyword searches, spreadsheets, etc.

Types of design information

i) Define four basic types of specification: grid, environmental requirements, design concept and material detail specification. Identify sub-types of design concept, viz: compatability and integrity (discussed above).

ii) Define types of information in specifications in terms of the design check, as in figure 5, and symbols used for their representation.

Handling design information

Data bases should provide the following functionality

i) A library of specifications and associated texts held in a consistent manner, from which design selection may be made. Each specification title and type should be held in a specification index. Standard specifications should be identified with details of standardizing body.

Each specification should be associated with a graphical symbol, devised to permit declaration of location and extent of application, and key design check parameters. Specification information should be categorized and associated with an appropriate representation processor. Specification data can be linked across several data bases associated with different representation processors.

ii) A catalogue of products as drawings and text showing material configuration, with manufacturers details and references to specifications held in the library of specifications (above).

iii) A project specification data base comprising environmental requirements and design concept specifications selected from the specification library, or created for the project, and products selected from the catalogue. A design project may produce
 * the specification for a one-off product
 * a standard specification or code of practice
 * catalogue information about a manufacturers product.

Processors are required to
i) create or alter a specification in the specifications library or project specification data base using appropriate representation to
 declare the scope of a specification as text, diagrams, etc
 define parameters and performance indicators
 define computations to generate parameters
 create a graphical symbol and label it with attributes
 declare parameter values associated with the symbol.
ii) Provide open access to all categories of information in the library and design data bases using facilities for interactive designer scrutiny and access by computer processes using
 * retrieval of information by keyword in specification titles
 * selective display of information by type (figure 5)
 * concurrent display of information for comparative purposes.
iii) Provide facilities to associate specifications to make up a product specification, a standard specification or a code of practice. Associations should be defined
 * spacially, nested and as sets.
Associations should be represented and displayed for designer scrutiny using graphical symbols (as proposed above) and with text (possibly tables).

Process requirements can be described in terms of software functionality for particular data types, such as word processing, hypertext, graphics, spreadsheets, etc. and graphical user interfaces.

Analysis of standards for computer representation

Contents of standard specifications and codes of practice should be marked-up with respect to
* specification title and type
* document functionality: title, contents, clause, index, etc
* type of symbolic representation: text, computations, graphics, photographic images, etc

Each clause, including informative, should be categorized by
* type of specification
* functionality in the design process (figure 5)
* whether nested or part of a set of specifications.

Information may be categorized in more than one way for use with different data handling processes.

Summary

Improved definitions of concepts such as standard specification, product and structure are needed to categorize specification information for computerization. A standard for the computer rpresentation of specifications should categorize specification information data and outline requirements of related data handling processes. Design information should be categorized in terms of both design process requirements and types of product specification and information.

Acknowledgement

The computer protoype was developed during a UK Science and Engineering Research Council project at the Department of Civil Engineering, University of Strathclyde, Scotland. Support and critical comment from Professor Iain MacLeod is acknowledged.

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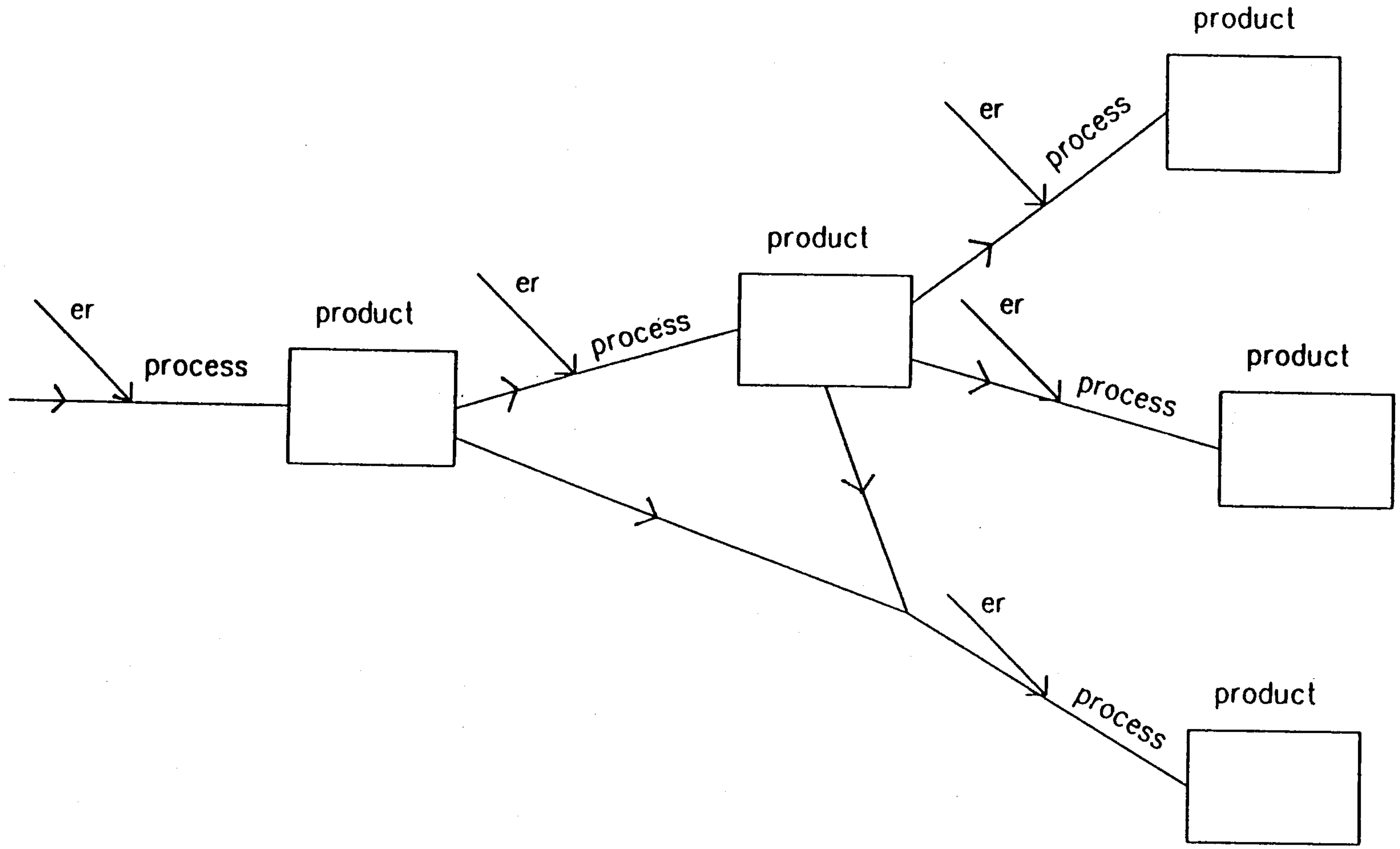


Figure 1 A product of a process provides functional specifications to suit environmental requirements (er) in a subsequent process.

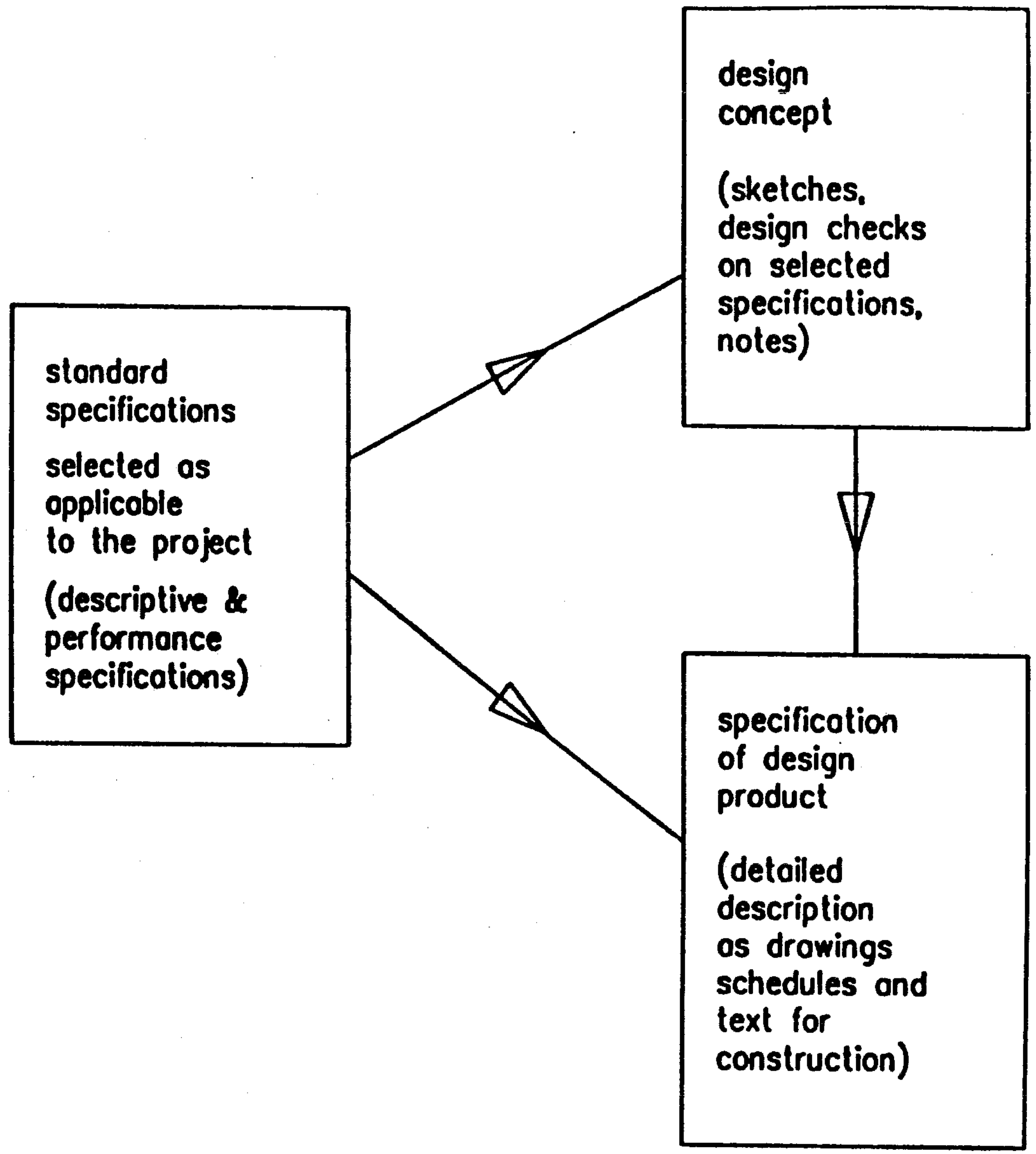


Figure 2 Types of design information and their relationship

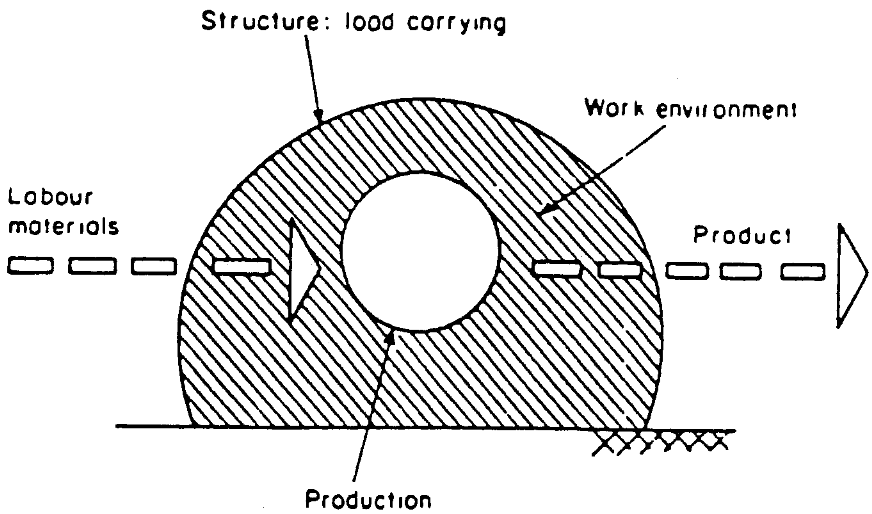


Figure 3 A diagrammatic representation of two processes containing production: a structure maintaining a work environment.

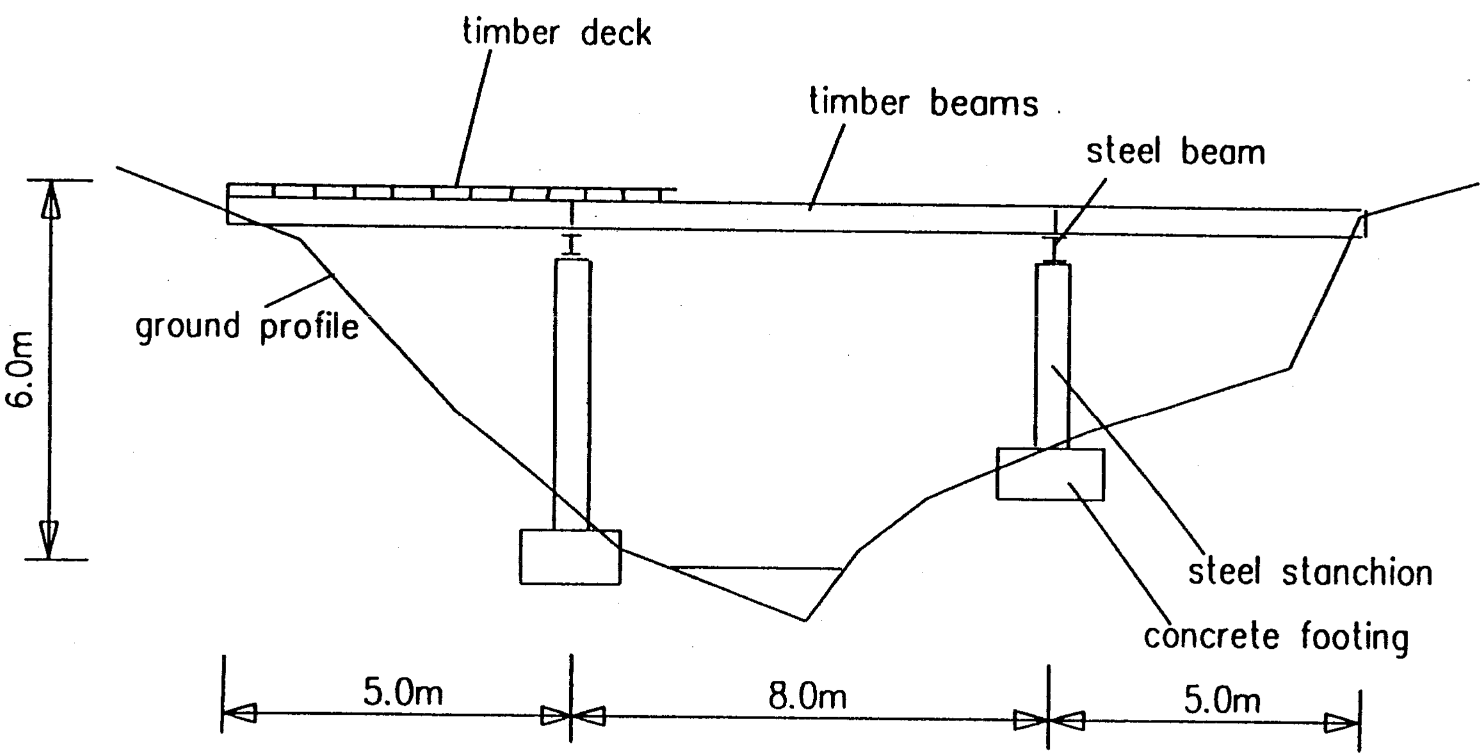


Figure 4 Symbolic representation of a structural design concept

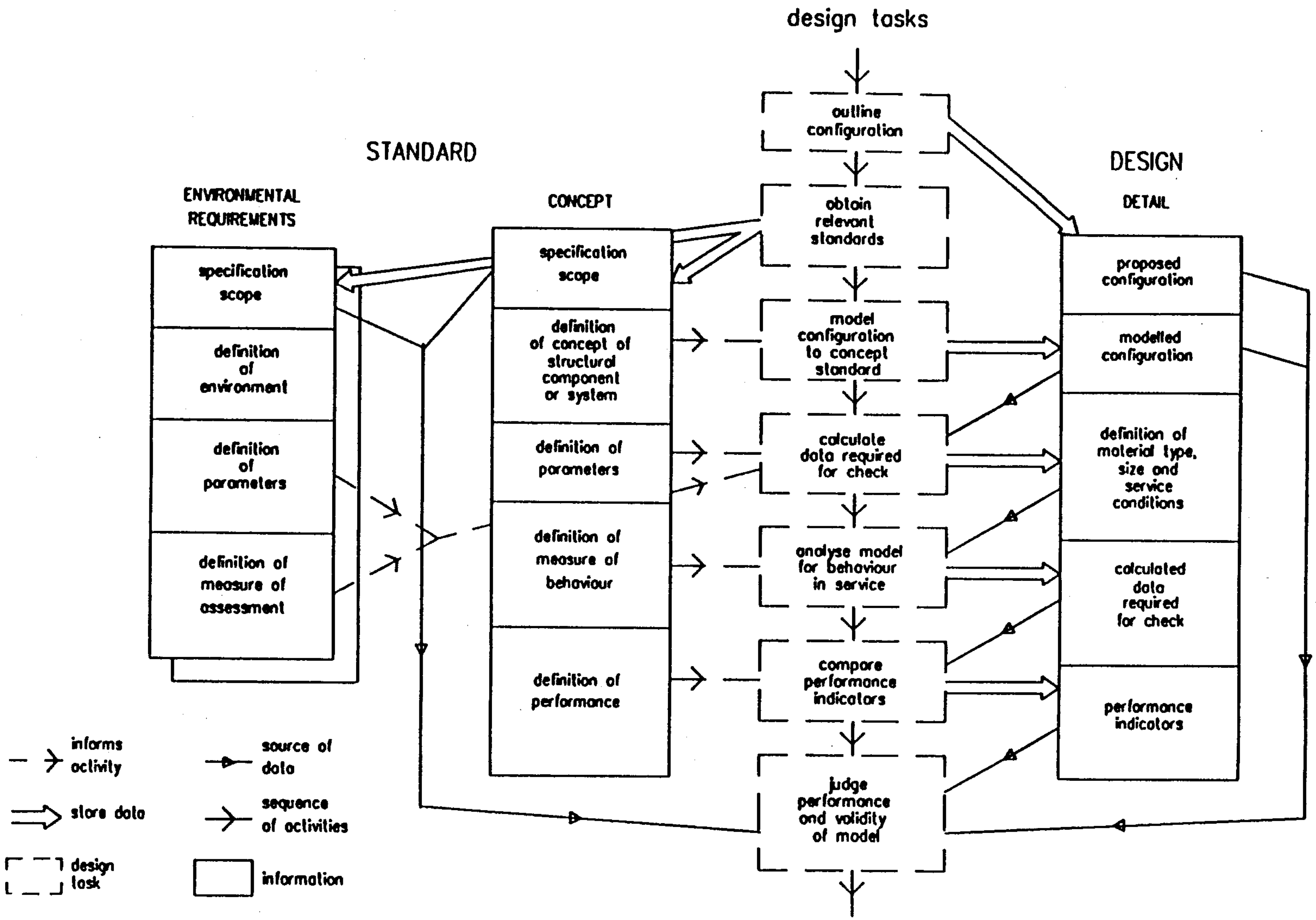


Figure 5 Activities and information involved in a design check.

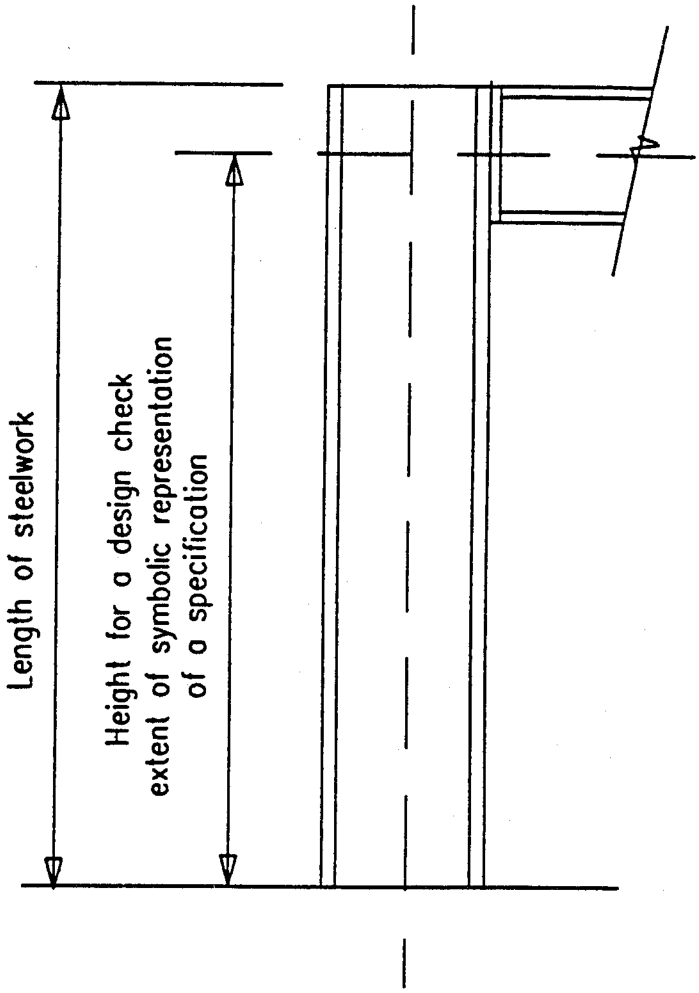
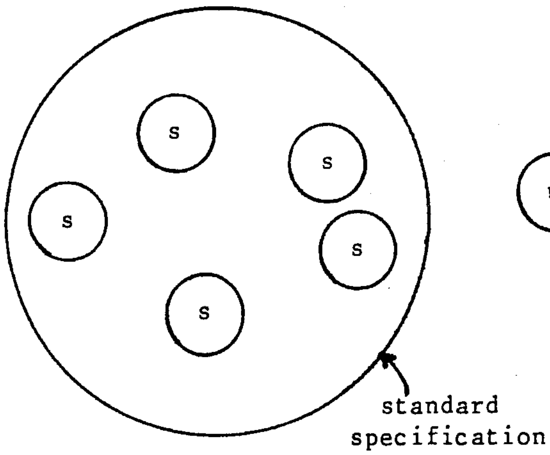


Figure 6 Column height for a design check and length of steelwork.



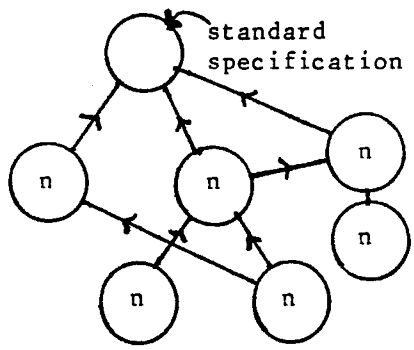


Figure 7 Set of specifications comprising a standard specification. Nested specifications referencing a standard specification.

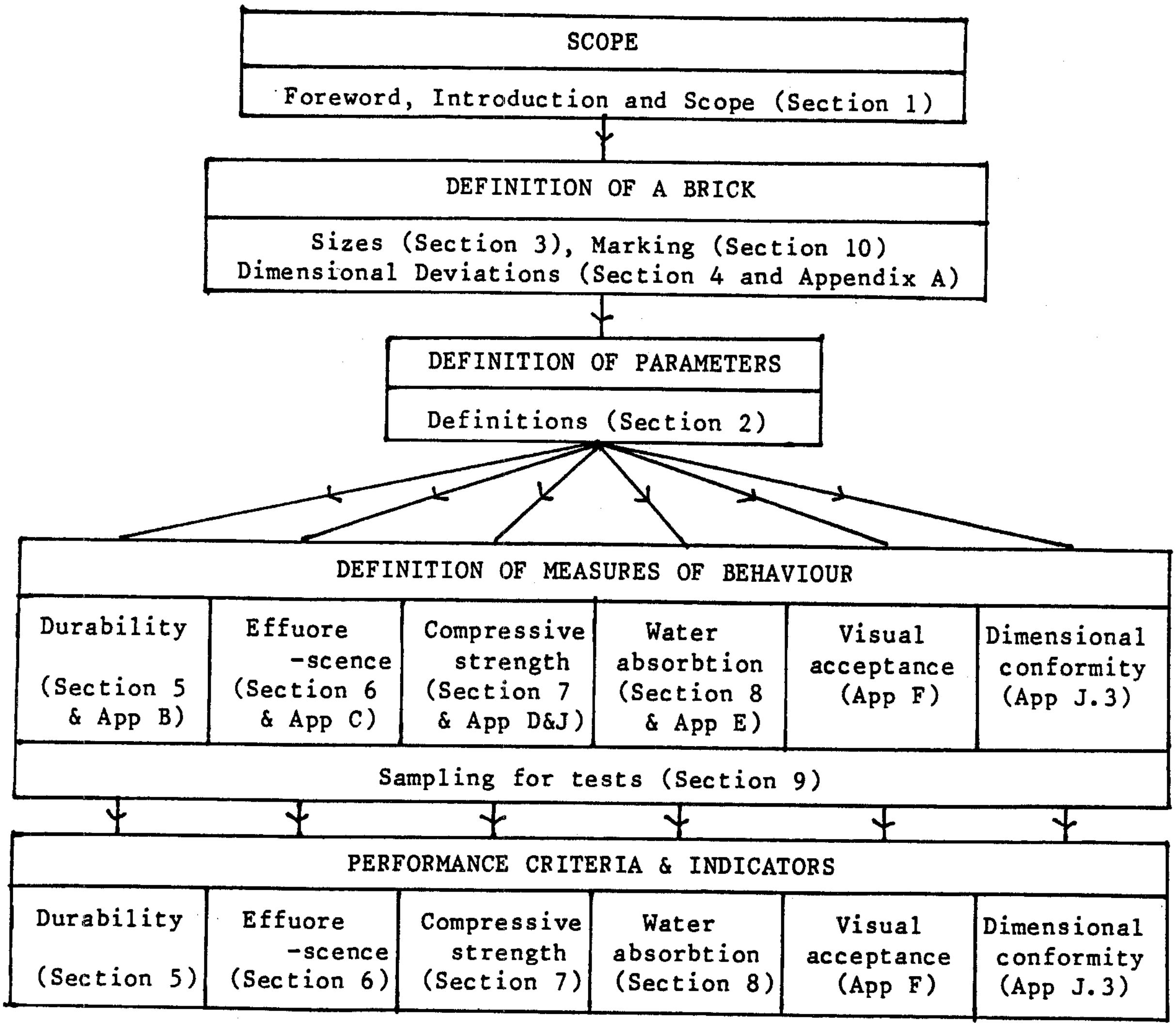
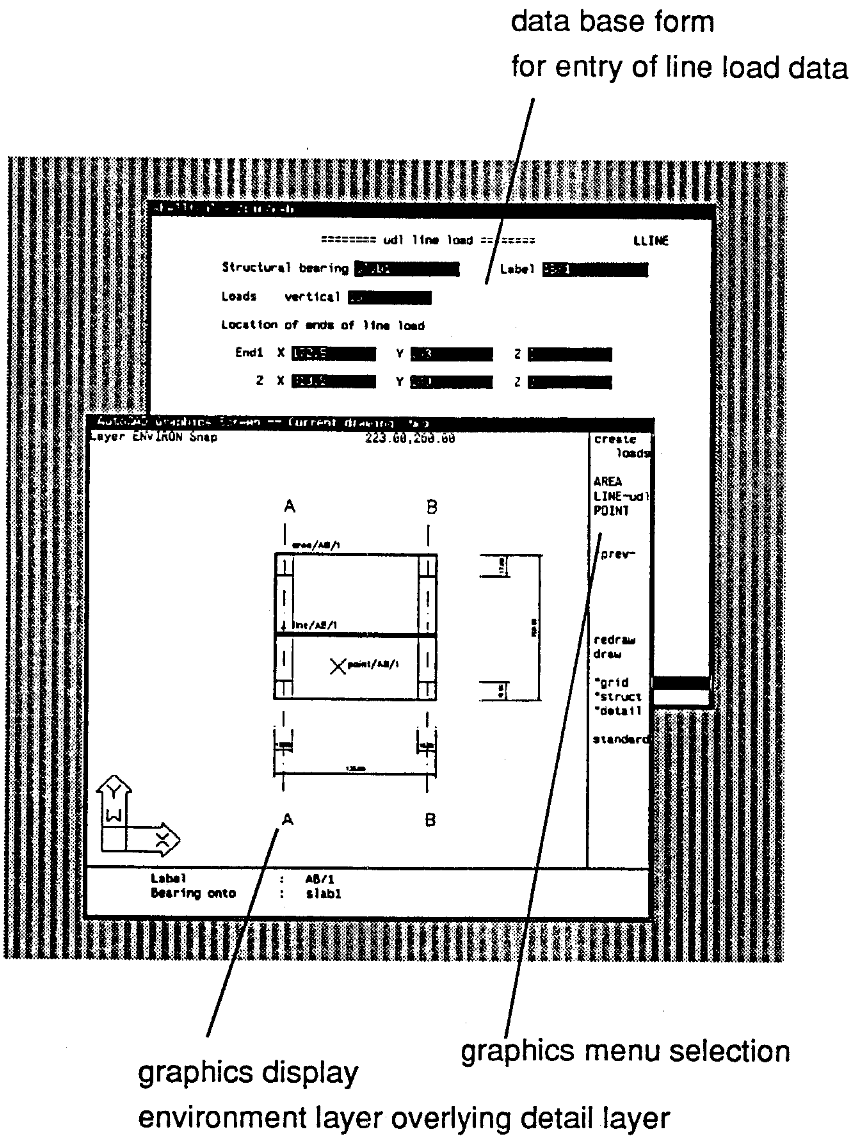
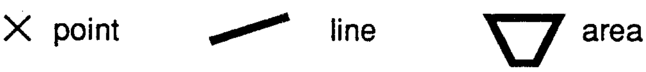


Figure 8 Six specifications comprise BS3921: a specification for clay bricks

specification information	information processing required	computer representation & processing
scope	explanation as text	database tables
definition of the specification of a part	explanation as text location of specification symbolic representation	database tables graphics (geometry) graphics (geometry & attributes)
definition of parameters	explanation as text values of descriptive parameters values of performance parameters	database tables database forms and tables spreadsheet & database tables
definition of measure of behaviour	calculations of behaviour analysis routines explanation as text	spreadsheet applications package database tables
performance indicators	computation comparison of indicators	spreadsheet database reports

Figure 9 Prototype representation of specification information





Load specification symbols

Figure 10

Environmental specification: symbol for point, line and area loads with data base form for line load details.

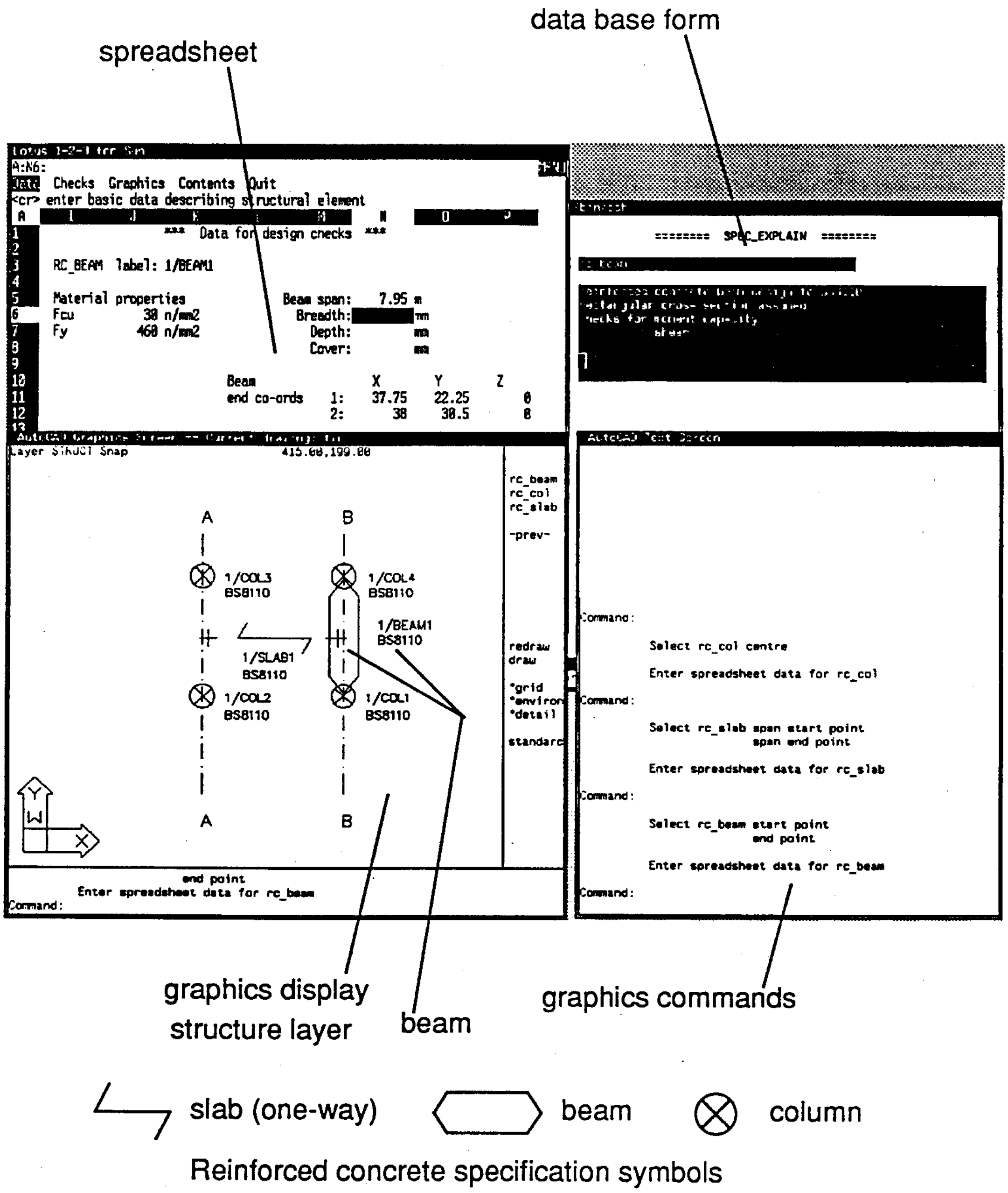


Figure 11

Structural concept specification: symbols for reinforced concrete beams, slab and columns with spreadsheet data entry for beam, label.

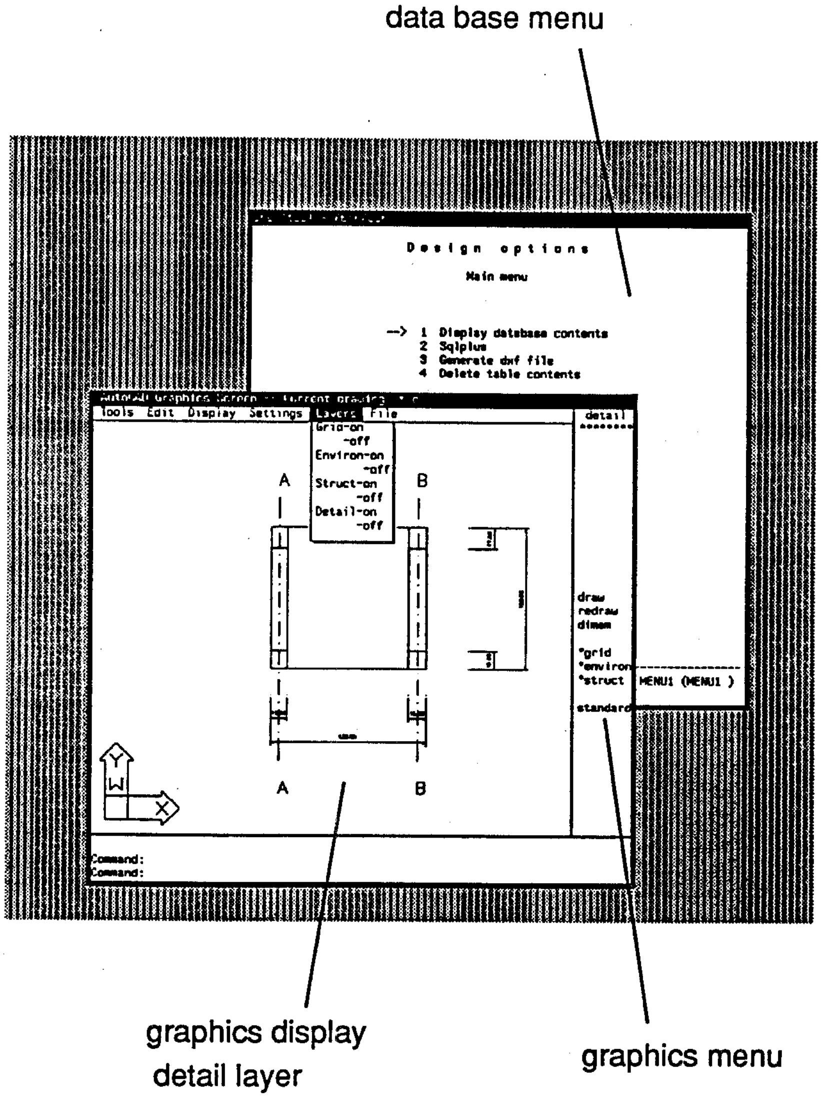


Figure 12

Detail of design product: plan on concrete beams slab and column.