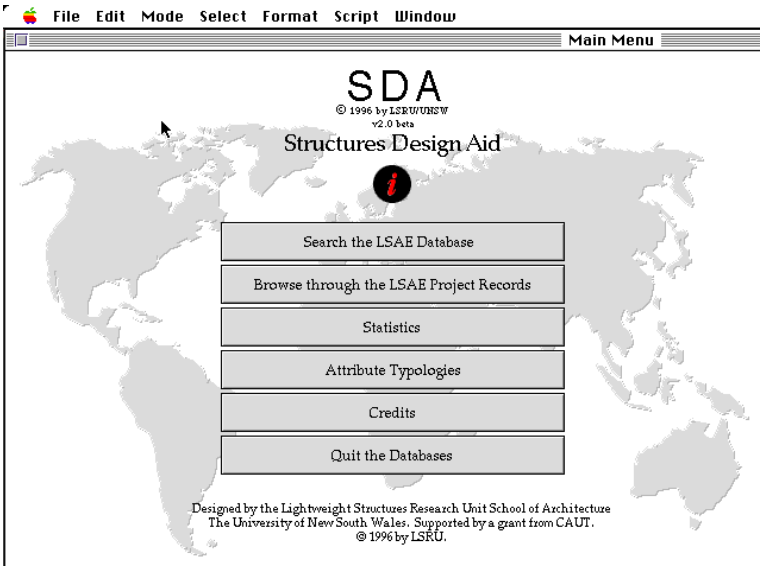
SDA– The Conceptual Structural Design Aid

Vinzenz Sedlak and Stephen Cox
Lightweight Structures Research Unit (LSRU)
School of Architecture / University of New South Wales
Sydney / Australia



SDA start up page

INTRODUCTION AND BACKGROUND

The Conceptual Structural Design Aid (SDA) emerged from a long standing project at the Lightweight Structures Research Unit (LSRU), the establishment of an interactive database of constructed examples of noteworthy (lightweight) structures (LSAE Database) assisted initially by a grant from the Australia Council, Design Arts Board.

Once established, the issue arose of how to best utilise the inherent power and capability of a computer–based database system for extensive cross–referencing and interactive searches. This led to subsequent research:

”The Design of Lightweight Structures in Architecture: The Development of a Theory of Application”, was funded by grants from the Australian Research Committee (ARC) and from both, Faculty and UNSW.

It's principal aim was to provide a basic theory for the understanding of (lightweight) structures and their application in architecture and building.

The project attempted to establish the relationship between use, shape and structure type of lightweight structures. Based on the hypothesis that there exists a logical grammar which rules these relationships, and once established, it can be used as a predictive design tool, an associative statistical analysis was undertaken on a data sample of 400 case studies. The basis of this hypothesis derived from a series of reports investigating the design methodologies of lightweight structures.[1]

The outcome from this research did not show clear associations between the target categories (use, shape and structure), however associations between sub–categories of these primary categories were demonstrated.

The project concluded in the recommendation that further analysis on a much larger number of case studies (1000 cases) was needed to obtain conclusive proof of the validity of the hypothesis.

The current SDA project, supported by a grant from the Committee for the Advancement of University Teaching (CAUT 1995), was established in order to link outcomes from previous research and to apply them to a working prototype of an interactive, computer–based design guide for the early conceptual design of lightweight structures.

It contains three main sections:

Firstly, a general guide on how to approach the design process. This includes prescriptions derived from the associative statistical analysis between the key categories of use, shape and structure ("Theory").

Secondly, a knowledge base containing a set of fully illustrated typologies of use, shape and structure which constitute the available design vocabulary.

Finally, a reference section of built examples of lightweight structures in Australia and internationally (LSAE Database).

THE SDA: THE CONCEPTUAL DESIGN AID FOR STRUCTURES IN ARCHITECTURE

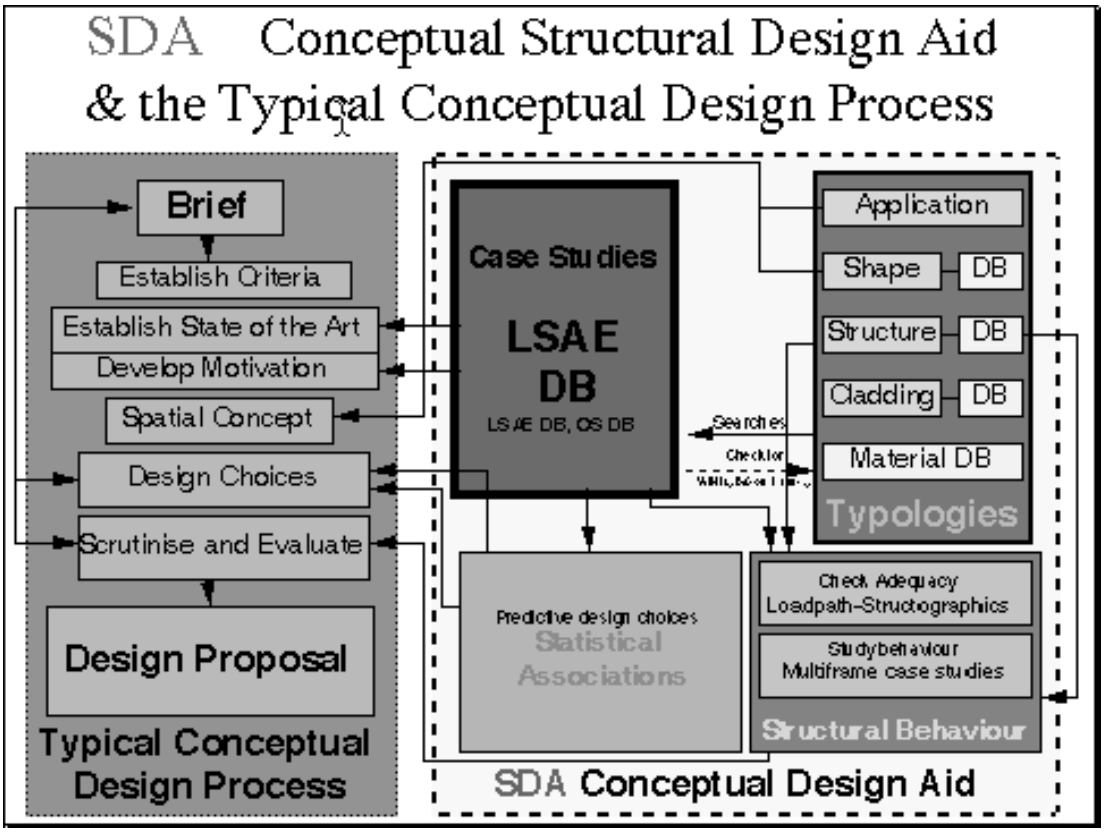
The key aim of the SDA is to provide architects, engineers, students and other designers with an interactive tool during the conceptual design stage. This allows design solutions to be established interactively, promotes valid decision making concerning structural system choice and facilitates assessing the impact of these choices on the building design.

SDA provides a case study database resource for rapid information access; a catalogue of possibilities related to shape, structure, use, building envelope and material as a design resource; and demonstrates the structural behaviour of selected case examples by computer simulation. It also has an intuitive graphical tool kit which examines the structural adequacy of a proposed building structure during the design process and provides guidance in choosing appropriate structure systems through statistical associations.

COMPONENTS OF THE SDA

Essentially the SDA is a combination of a number of different databases. These databases fit together into a single package that allows swift movement (interaction) between the various components (see below).

[1] SEDLAK, Vinzenz, 'A Design Methodology for Lightweight Structures', Proceedings of the ANZAScA Conference, Sydney, Department of Architecture and Design Science, University of Sydney, 1993.
SEDLAK, Vinzenz, "Architecture and Lightweight Structures: a Methodical Design Approach', Proceedings of the IASS–ASCE International Symposium, Georgia, USA, 1994, pp., 1010–1023.



SDA and the typical conceptual structural design process

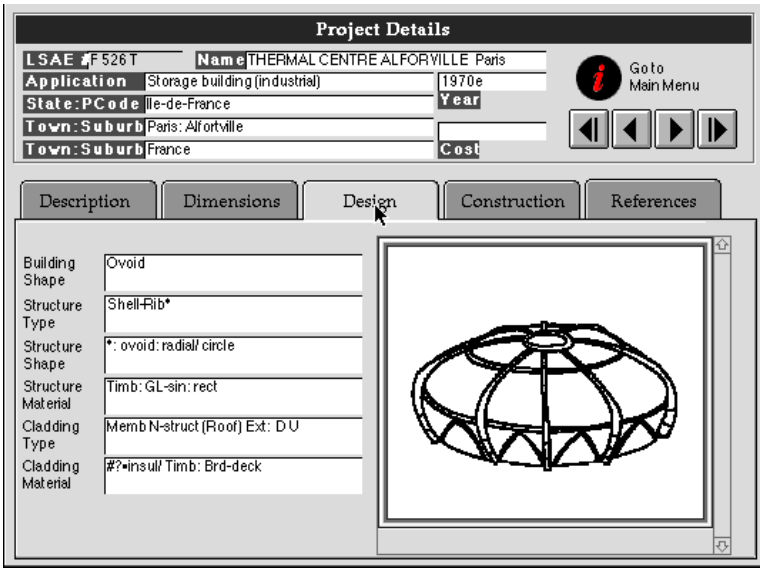
The databases were developed in FilemakerPro 2.1 on Apple Macintosh computers and then converted to FilemakerPro 3.0 format. Resorting to professional assistance a user friendly interface was developed.

FilemakerPro 3.0 is a cross–platform (Apple and IBM/PC–compatible computers) relational database, that is fast and powerful but is easy to use.

The benefits of this system over traditional methods are numerous.

The SDA allows simultaneous consideration of structure and architecture (shape, use, envelope), it alleviates user insecurity in matters of structural system choice (which may occur due to lack of knowledge and/or experience) and it encourages playful interaction. It also provides on–call factual information based on real case studies that would otherwise not be readily available. The areas of structure and construction are integrated into one single package rather than treated as disparate and often competing units. Once established as an integrated information system, SDA also has a capacity to expand into all areas of architectural and building design knowledge such as environment, aesthetics, historical precedence and so–on. Finally the user friendly environment allows users to explore, learn and to proceed at their own pace.

THE CASE STUDY (LSAE) DATABASE



Sample LSAE database page

Currently the database has 1771 projects partially or fully entered.

400 projects were selected for statistical analysis. New projects are regularly entered keeping track with the developed of architecture in Australia and overseas.

LSAE DATABASE FORMAT

The database is divided up into categories that allow comparison between similar projects. These categories are the result of the research into the development of vocabularies of each category. For further information refer to the footnoted documents.[2]

These are the main categories used by the case study database:

Application

Each project in the LSAE database is defined as having a primary application. This is what the building is primarily used for. Some buildings have several applications.

Building Shape

This category describes the overall shape of the building. It is not concerned with details of the structure (also known as building volume shape).

Structure Type

The Structure Type category identifies ,for each case study, the primary system that transfers building loads into the ground.

[2]Reference documents:

SEDLAK, Vinzenz, 'The Morphological Approach to the Teaching of Structures', Proceedings from the international Conference on Lightweight Structure in Architecture, Sydney 1986, Unisearch Ltd., 1987.

LOH, Seok Kuan, 'A Vocabulary of Shape and Structure Type in Australian Applications of Lightweight Structures', Dissertation, UNSW, 1989.

SHAN, Ruan, WONG, Kah Loon and WONG King Lai, 'Cladding Systems, Cladding Materials and Structural Materials', Research paper, UNSW, 1990.

SIKORA, Wojciech Jakub, 'Typology of Cladding Systems', Research paper, LSRU, UNSW, 1992.

KOK, Desmond, Eng Tiong, 'Structure System Choices for the Conceptual Design of Exhibition Buildings', A Special Research project, LSRU, UNSW, 1994.

Material

Materials used in the cladding and structural systems of each case study are recorded in the material category.

Cladding

Given that a building must support loads and protect the internal spaces from environmental effects, cladding is that part which serves the latter function. In some buildings the structure and the cladding are combined because they are the same object.

These categories form the 'subject' headings for the typology documents.

Other information included is:

Country: indicating where the particular project was built.

Year: noting the year that the project was completed.

Span: a measure of the distance that the structure acts.

Plan Area: the amount of area the building occupies in plan.

SUPPORTING DATABASES

To complement the LSAE database the SDA has a number of other databases which are grouped into two distinct types:

"Typology" databases and "Example" databases.

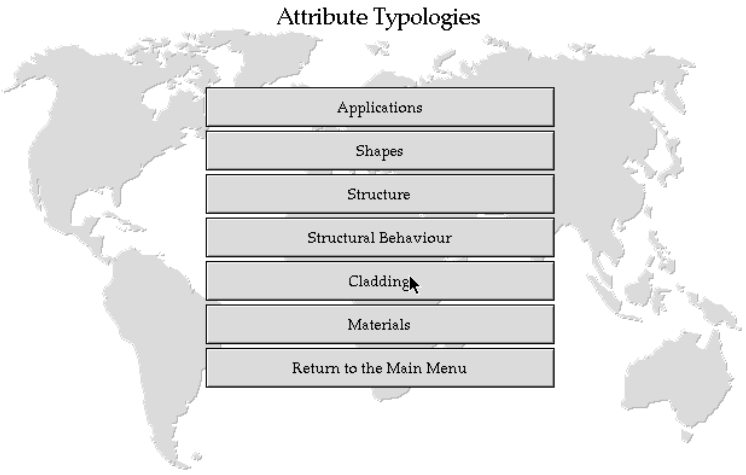
Typology databases contain information that define a group of specific sub–categories. For example, the "Typology of Structure" database, contains articles on different structural systems (a sub–category of structure).

For instance, a designer would find information and definition on "space–grid" structures.

Example databases are different from the typology databases in that they are catalogues of examples, rather than definitions of categories.

For example, the shape (example) database contains examples of a large range of shapes. This database would enable a designer to examine, say, prismatic shapes in general, or to examine a single prism shape. Where possible example databases complement typology databases.

These supporting databases are now described in more detail.

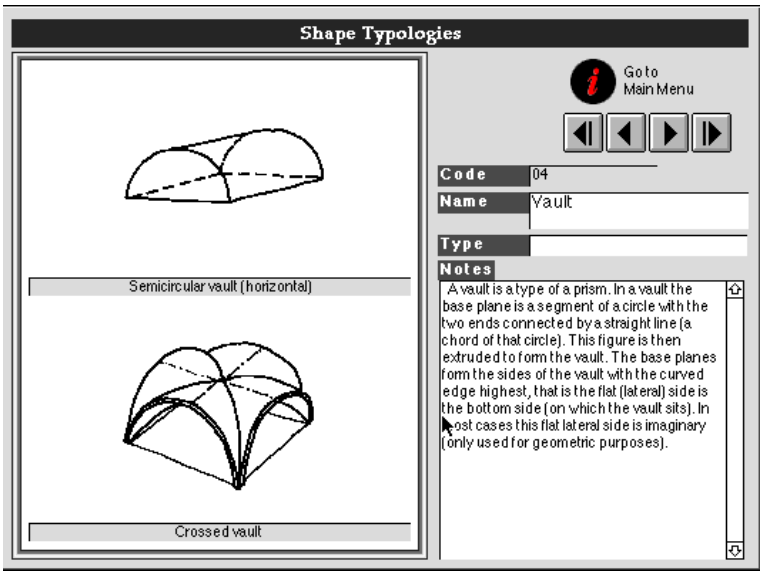


Supporting (attribute) databases

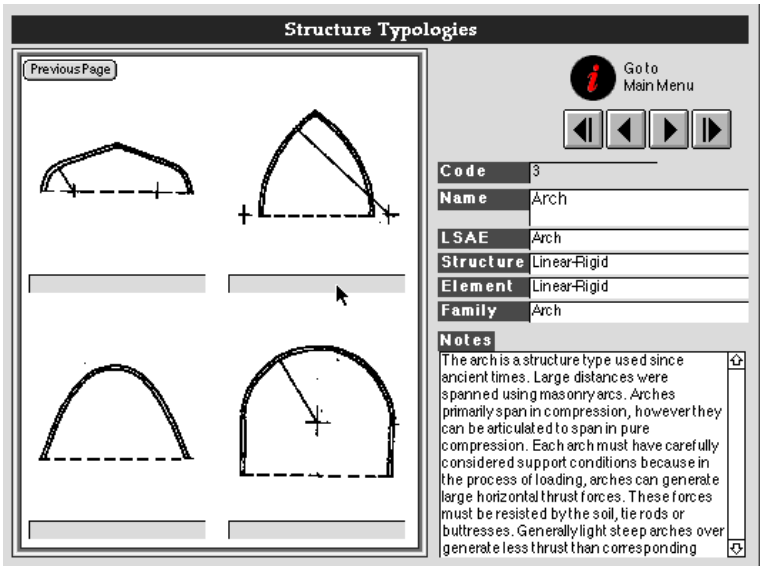
TYPOLOGY DATABASES

There are four typology databases.

The **Typology of Shape** database, examines what constitutes a particular shape, and why one group of shapes is different to another.

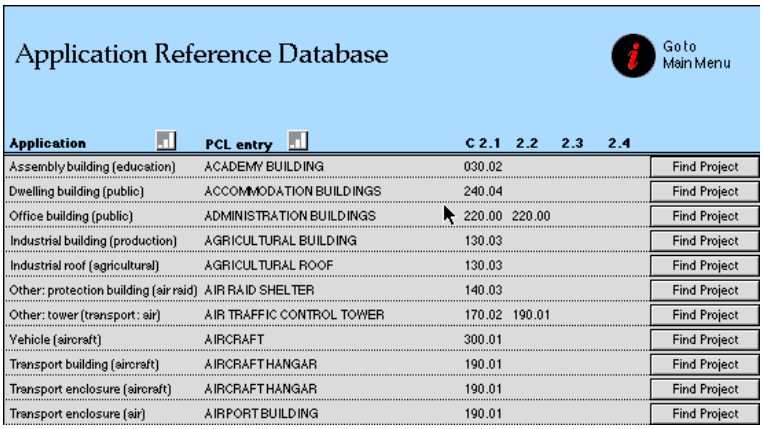


The **Typology of Structure** database examines the different structure types available and briefly describes each structure type.



Typology of structure

The **Typology of Application** database lists building applications and links these to the associated term in the SDA. The database also provides a cross–platform link between the SDA and ICONDA (the International Construction Database). This enables generic SDA terms to be directly linked to the internationally recognized system.

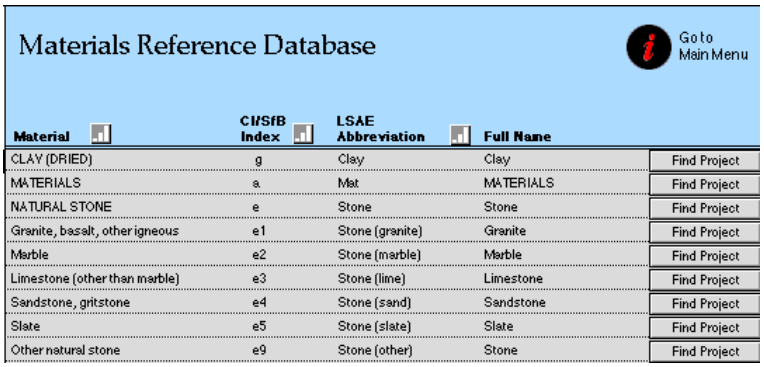


Application Reference Database

Goto Main Menu

Application	PCL entry	C 2.1	2.2	2.3	2.4	
Assembly building (education)	ACADEMY BUILDING	030.02				Find Project
Dwelling building (public)	ACCOMMODATION BUILDINGS	240.04				Find Project
Office building (public)	ADMINISTRATION BUILDINGS	220.00	220.00			Find Project
Industrial building (production)	AGRICULTURAL BUILDING	130.03				Find Project
Industrial roof (agricultural)	AGRICULTURAL ROOF	130.03				Find Project
Other: protection building (air raid)	AIR RAID SHELTER	140.03				Find Project
Other: tower (transport: air)	AIR TRAFFIC CONTROL TOWER	170.02	190.01			Find Project
Vehicle (aircraft)	AIRCRAFT	300.01				Find Project
Transport building (aircraft)	AIRCRAFT HANGAR	190.01				Find Project
Transport enclosure (aircraft)	AIRCRAFT HANGAR	190.01				Find Project
Transport enclosure (air)	AIRPORT BUILDING	190.01				Find Project

Similarly the **Typology of Material** database links different materials to the appropriate SDA term. The Typology of Material database also links SDA terms to the appropriate CI/SfB term (the internationally recognised construction products and materials classification system developed by the Royal Institute of British Architects).



Materials Reference Database

Goto Main Menu

Material	CI/SfB Index	LSAE Abbreviation	Full Name	
CLAY (DRIED)	g	Clay	Clay	Find Project
MATERIALS	a	Mat	MATERIALS	Find Project
NATURAL STONE	e	Stone	Stone	Find Project
Granite, basalt, other igneous	e1	Stone (granite)	Granite	Find Project
Marble	e2	Stone (marble)	Marble	Find Project
Limestone (other than marble)	e3	Stone (lime)	Limestone	Find Project
Sandstone, gritstone	e4	Stone (sand)	Sandstone	Find Project
Slate	e5	Stone (slate)	Slate	Find Project
Other natural stone	e9	Stone (other)	Stone	Find Project

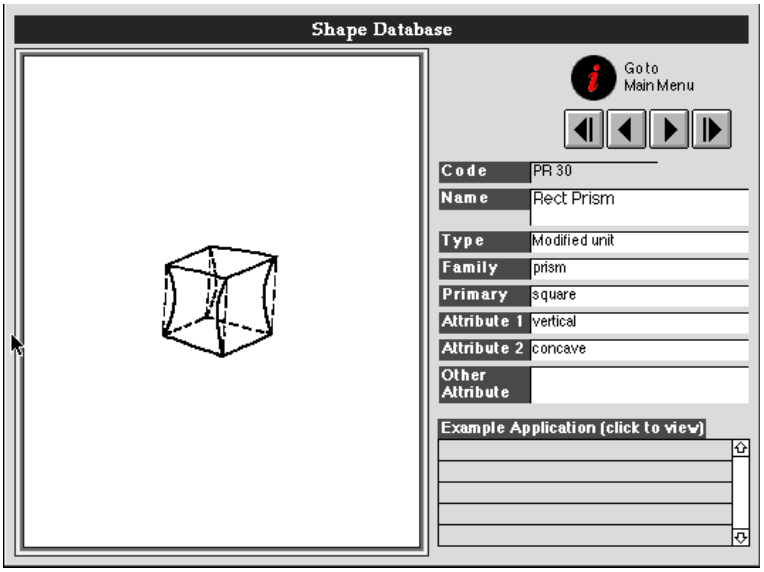
Typology of material database

A fifth database, the **Typology of Cladding**, is under development and will be incorporated into the SDA at a later stage.

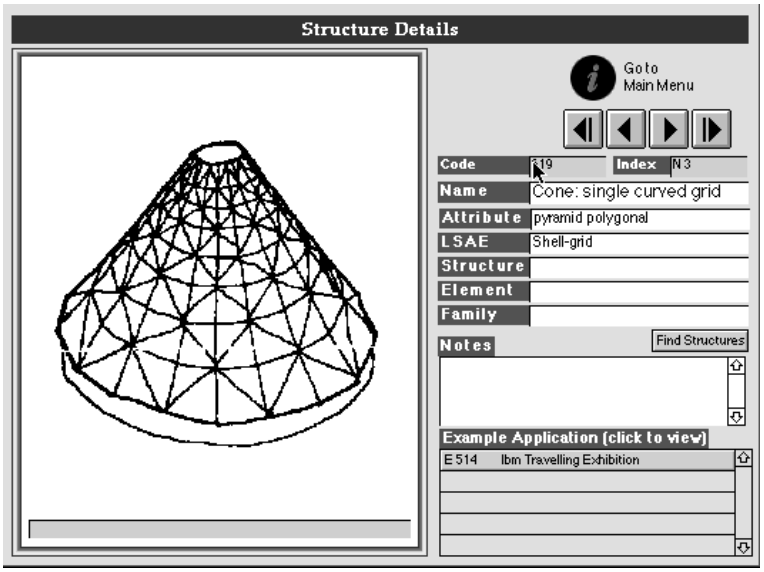
EXAMPLE DATABASES

There are four example databases.

The **Shape database** contains different shapes. Each shape is catalogued under a specific shape family. ”Shape family” refers to the basic shape that each entry is derived from. Entries are described using general terms and also with the SDA terminology. Every entry contains an illustration. There are links with the LSAE database, which allows real architectural examples to be found and compared to the Shape database example

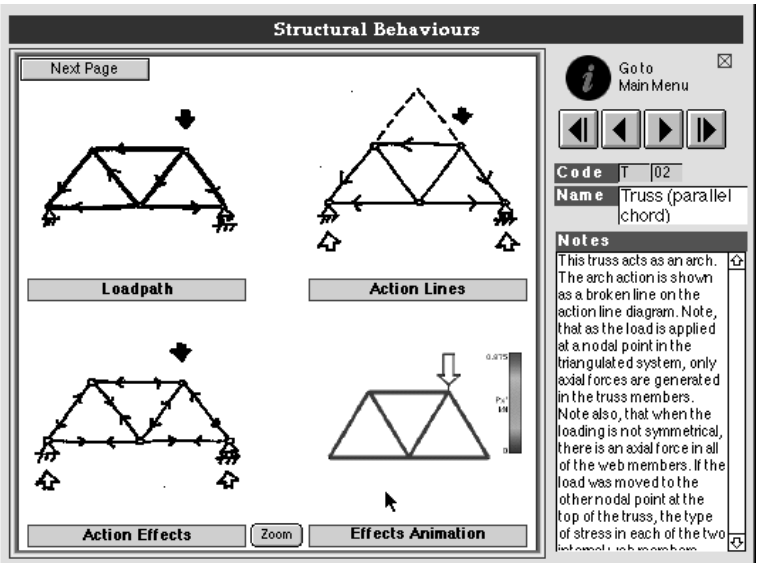


The **Structure Database** is similar to the Shape database. It contains a large number of examples, which are catalogued to a general, or basic, form of structure. Examples are described in both general terms and using the SDA terminology. Each entry is illustrated and there are links to the LSAE database.



Structure database

The **Structural Behaviour Database** examines a number of generic structural systems and demonstrates the effects of loading on that system.



Each part graphically indicates a component of loading.

Load Paths: indicate the path(s) which the load travels, from the point(s) of load application to the supporting ground.

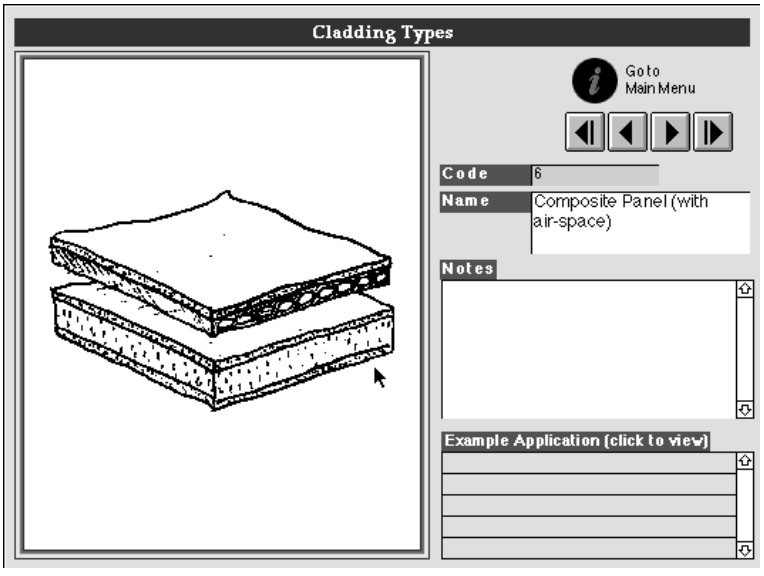
Action Lines: demonstrate the external force system of actions and reactions.

Action Effects: display the element stresses generated by these actions.

Structographics: a graphical representation of the internal forces of a structure under loading as well as indicating the inherent structural stability of the members within that structure.

Animation: a computer animation of the structure deforming under load indicating the intensity of element stress in bending or axial force (based on the program ”Multiframe” by Graphsoft)

The **Cladding Database** contains a number of examples of different cladding systems. Entries are illustrated and are described in general and SDA terms. At this stage the cladding database is not as developed as the other example databases.



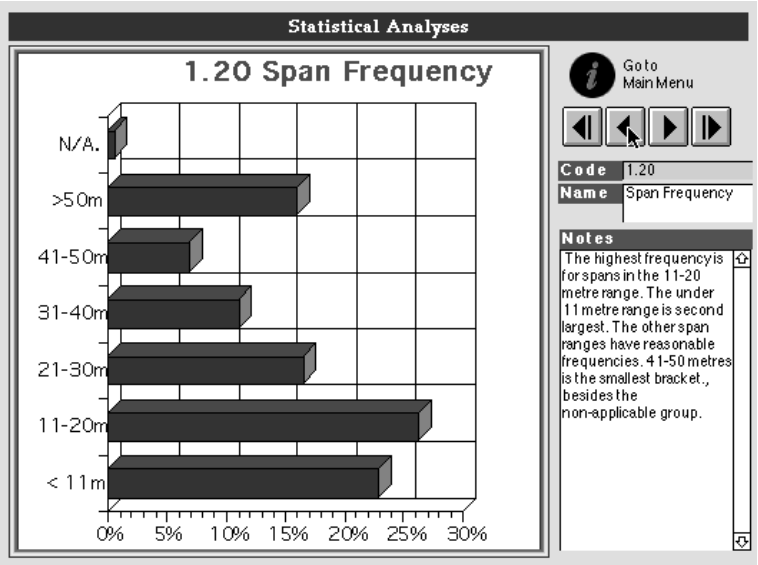
Cladding database

ASSOCIATED DATABASES

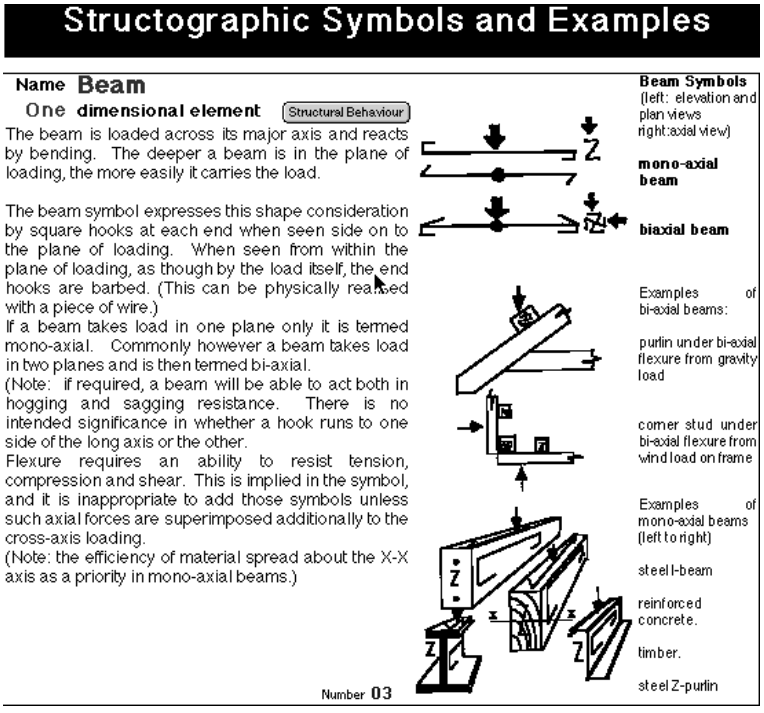
To complement the LSAE, Typology and Example databases there are two associated databases:

The **Statistics Database** is a collection of graphs summarising associations between the different primary and sub categories. It is based on the outcome from the statistical analysis conducted on

the LSAE database. The Statistics Database is useful for determining which categories are dependent or affected by other categories. For example, that some cladding materials are more appropriate than others given certain structural materials.



The **Structographics Definition Database** provides a list of Structographics definitions. Each definition is accompanied with illustrations and a brief description.



Structographics definition database

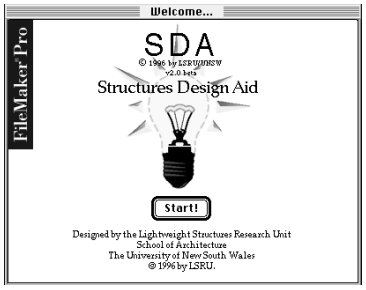
USING THE SDA

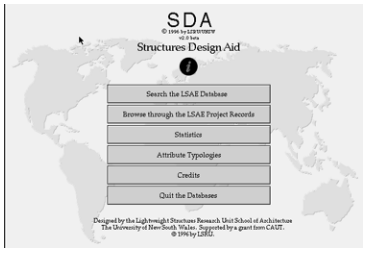
The is no distinct method of using the SDA, hence to some degree those who use it may find their own way around the package. However for the purposes of assisting the conceptual design process there are three basic methods. In reality the actual method of use would be a combination of two or all of these methods.

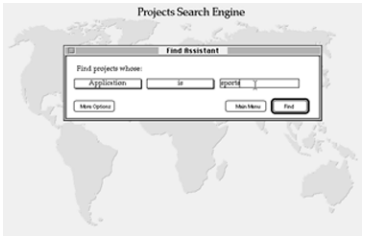
1. Early in the Conceptual Design Process

The method is applicable in the first stages of the conceptual design process, where no major decisions are yet made concerning the nature of the project. In this stage a designer seeks information of a general nature regarding a variety of topics.

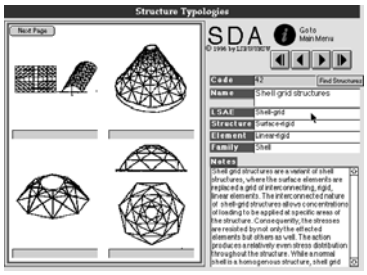
At first a designer would browse through the SDA discovering areas of interest or design choice. The LSAE database would be a good place to start. In this section she/he may find terms or elements that she/he is unfamiliar with or so she/he might then access another database to address this problem. For example, the designer finds an entry with a shell–grid structure, but is unsure as to what exactly constitutes a shell–grid structure. The designer could then access the typology of structure database to find information on shell–grid structures. Knowing now what a shell–grid is, she/he could look at examples of buildings that use shell–grid structures in the LSAE database or look at similar types of structures in the structure database. Using the structural behaviour database she/he could examine the structural behaviour of shell–grid structures.







Start SDA Choose to browse Specify full page/brief/1 line

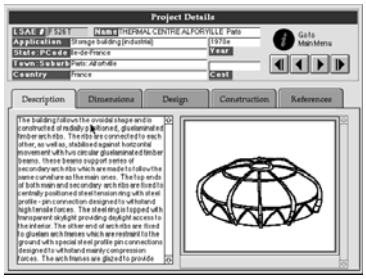


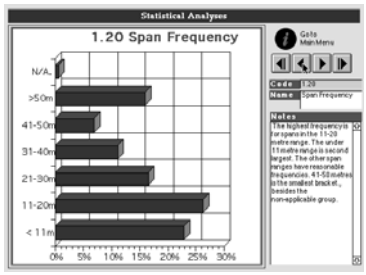
Query Browse structure type Browse similar structures

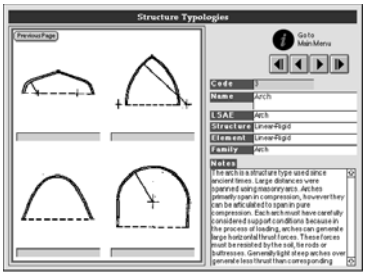
2. During the Conceptual Design Process

Midway through the conceptual design process the designer has made some decisions on the nature of the current project and now seeks to examine the consequences of these decisions on the rest of the project or find more specific information on areas of the project. The SDA is a useful tool to achieve this.

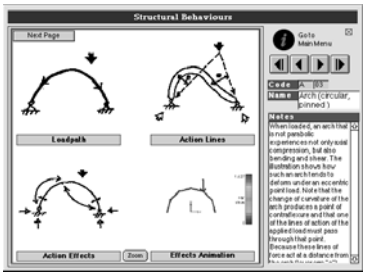
At this stage the designer would probably perform a search in the LSAE database to examine other buildings which have common features with the current project. From this she/he might examine other component that these projects have in general. She/He might consult the statistics database to examine association between categories. Or she/he might consult the structural behaviour database to look in detail at the effect of loading on his particular structure. From this point other databases would be consulted to seek, verify and evaluate design choices.







Browse similar cases Consult statistics Shape possibilities

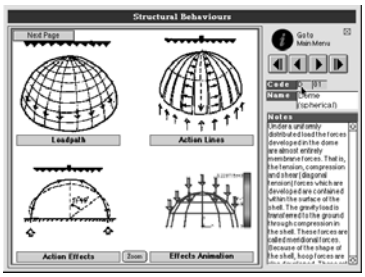


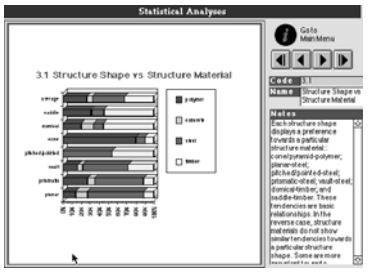
Structural behaviour

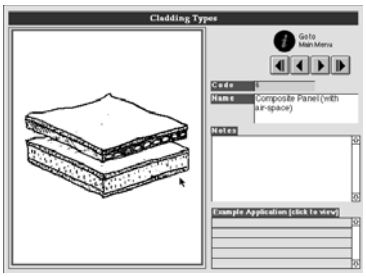
3. Late in the Conceptual Design Process

Late in the conceptual design process the designer may be interested in specific information on possible design solutions (options).

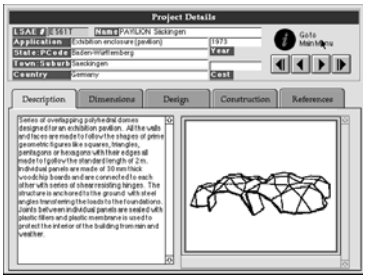
She/He might examine the structural behaviour database to look at the structural performance of a chosen system(s). She/He might check the statistics database for appropriate cladding materials for a particular structural application. At this stage specific searches of the LSAE database can be performed by simultaneous searches in several categories. If further information is required on particular constructed examples references listed in the LSAE database can be consulted.

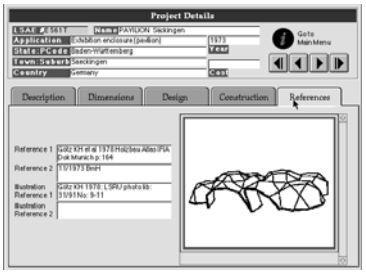






Structure Behaviour Structure vs. Material Statistics Cladding Types





Read similar cases Check references

ACKNOWLEDGMENTS

SDA is the result of work at LSRU/UNSW over a 10 year period (1986–1996) involving numerous individuals including staff, students and consultants. The following people have been involved in various stages of the project and their combined efforts made SDA possible:

Peter Bycroft, Statistics Consultant

Nick Duke, Filemaker Database Development Consultant

R. Waldo Granwal, Structographics and ”Multiframe” Consultant

Vinzenz Sedlak, Project Leader

Barry Wollaston, Structural Behaviour Consultant

Project Assistants:

Stephen Cox, Steven Debello, Seok Kuan Loh, Jonathan Peart, Matthew Semple, Wojciech Jakub Sikora

Contributing Student Projects:

Dawn Carrol, Dominic Chung, Ian William Downes, Ying How Huang, Goh Bak Hooi, Siva Shankar Kanagasabai, Wooi Khean Khor, Dinos Kypriano, Tony Lee, Barbara Lifson, Henry Luk, Robert Neill, Brett Pollard, Shan Ruan, Desmond Kok Eng Tiong, , Kai Loon Wong, King Lai Wong, Ming–Yang Xu, and Justin Yu.

The project was supported at various stages of its development by:

Australia Design Council, Australian Research Committee, Committee for the Advancement of University Teaching, Faculty of Architecture UNSW and by the University of New South Wales.