International Conference on Textile Composites and Inflatable Structures
STRUCTURAL MEMBRANES 2011
E. Oñate, B. Kröplin and K.-U.Bletzinger (Eds)

DATABASE INTERACTIVE AND ANALYSIS OF THE PNEUMATIC ENVELOPE SYSTEMS, THROUGH THE STUDY OF THEIR MAIN QUALITATIVE PARAMETERS

ALBERTO GÓMEZ-GONZÁLEZ [*], JAVIER NEILA[†] AND JUAN MONJO[†]

[*] Grupo de Investigación ABIO_Arquitectura Bioclimática en un Entorno Sostenible
Departamento de Construcción y Tecnología Arquitectónicas
Escuela Técnica Superior de Arquitectura. Universidad Politécnica de Madrid
Avda. Juan de Herrera 4, 28040, Madrid
e-mail: alberto.gomez.gonzalez@upm.es

Key words: Pneumatic envelope systems, database interactive, proposals compilation
Summary. The design of pneumatic envelope systems has experienced an important development since the beginning of the 20th century; when military, social and economic necessities required new systems to cover large rooms with easy and quickly technologies.

However, many projects and experiences have been developed in periods without constant compilation and cataloguing studies. The historical review of these technologies has had an intermittent analyse process; existing periods of maximal researches, like the 70´s and others with lower publication levels, like the ´80s and early ´90s.

Because of that, the research had the main objective of developing a new critical and historical review of the evolution of this technology; in order to complement low catalogued periods and also to allow the study of the main conditions that had influenced the use of pneumatic envelopes applied in architecture.

The methodology of study has been focussed on the location and documentation of projects, not only constructed also utopian and non built proposals, which qualitative properties have supposed special innovation in the field of this technology. In this way, it has been studied the following parameters in each of the documented projects: contextual, morphological, functional, constructive, climatic and comfort-energy efficiency.

The organization methodology has been coordinated by the construction of an interactive and open data-base, helping not only the individual study of each proposal, also the comparative analyse of different projects, associated to the different parameters and sub-parameters of characterization.

More than 660 different strategies have been catalogued, since the first patent of F.W. Lanchester in 1917, to the last projects developed in 2010. The proposal of the interactive database also has helped to define a dynamic, non-linear and open study of the results, allowing the comparison between the main pneumatic envelope typologies and the selection of new research strategies in this engineering and architectural field.

1 INTRODUCTION

The pneumatic envelope systems have experienced an important development in the last century. However, this technology has suffered different documentation processes; with high publication periods followed by others with very low volume of articles or books.

By studying the main Spanish and International library database sources in the architectural context, three different periods can be differentiated: The seventies and the first decade of the 20. Century reached the highest publications volume, while in the eighties and early nineties the proposals decreased considerably. The variability of the economic, social and technical conditions on the last 40 years, have favored the discontinuity of the cataloguing and documentation of the pneumatic envelope systems.

The following library database sources have been studied:

_REBIUN. Red de Bibliotecas Universitarias / Spanish Academic Library Network.

_Delegaciones de Colegios Oficiales de Arquitectos de España / Regional Libraries of the Official Architects Spanish Associations.

_ILEK Institute. Institute for Lightweight Structures and Conceptual Design (ILEK) at the University of Stuttgart.

_Avery Index to Architectural Periodicals of the Columbia University.

According to the great volume of periodical publications of the Avery Index database source; the following figure (fig. 1) represents the relation between periods with high interest about pneumatic systems and those with low volume of published articles.

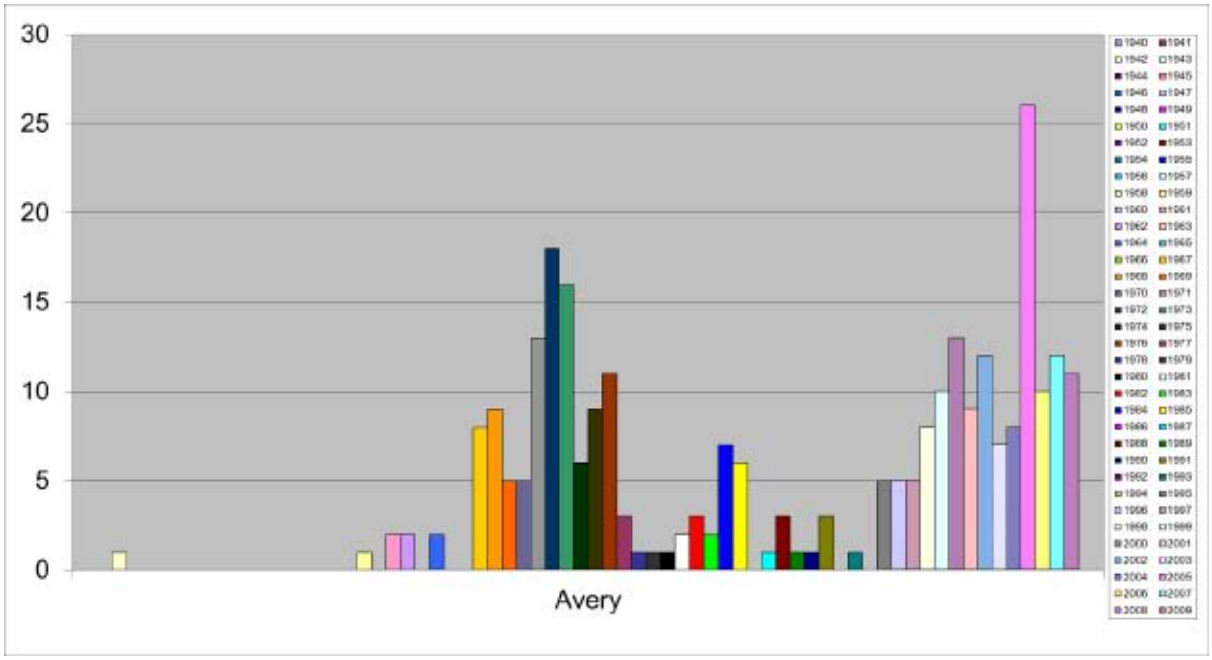

Figure 1: Volume of articles compiled in the Avery Index. Diagram: Own elaboration

The type and characteristics of publications have evolved according to each period, from the great compilation of projects of the seventies to the currently diffusion by technical articles. In this sense, it has been observed that while the first books were focused on the compilation of large quantity of different projects and pneumatic typologies, in order to analyze and promote the characteristics of this technology; the current publications are more focused on the study of particular projects and specific constructive systems, than in the comparison between different strategies.

In this way, the Roger Dent (1971) [1] and Thomas Herzog (1976) [2] publications are still the international reference compilation of pneumatic systems. Also, more recent studies are the Karsten Moritz compilation about ETFE projects (2007) [3] or the Wolfgang Naumer doctoral thesis about pneumatic systems (1999) [4]. However, an open source and interactive database with such amount of projects, including different pneumatic typologies and materials, had still not been developed.

2 OBJECTIVES

2.1 Main objective

The following in-depth study has been made with the objective of giving continuity to the proposals documentation that has been developed in the different periods, from the first patents to the current projects. Also, the study purpose is to design a compilation system that allows detailed and qualitative analysis of the pneumatic architectural typologies, by the study of the main parameters which characterize them.

In this way, an interactive and open database has been developed, in order to allow the evolution analysis of this systems and his gradually complementation as new projects arise. The interactive database allows a combined, linear and nonlinear reading of the documented systems; and also the open source character favors the proposals diffusion and the introduction of new pneumatic strategies. These properties complement the static nature of conventional methods, such as databases and networks of traditional academic libraries.

The database has been organized in different parameters in order to help a critical review of the pneumatic systems development, from their beginning to nowadays, through their contextual, morphological, functional, constructive, climatic and energetic conditions.

2.2 Specific objectives

The development of the interactive database has helped also to achieve the following specific objectives:

_Analysis and classification of the different systems, through the isolated study of each analysis parameter (morphological, functional, technical, energetic, social and economic)

_Global study of the pneumatic skin systems development influences, through the comparative relation between the different analysis parameters.

_Identify the main points of inflection of this technology and study of the main grounds of pneumatic systems development.

_Identify the new lines of research. Redefine strategies and approach to new proposals.

3 METHODOLOGY

The compilation methodology has been organized in two types of elements: The open source and interactive database and the summary files.

In order to allow the comparative analysis between projects, different parameters have been considered to define the main characteristics of the pneumatic envelope systems; so the projects have been selected according to these qualitative parameters. In this way, those proposals which are repeatable have only be considered one time; and those which no represent any innovation respect the selected parameters, will be omitted. In this way, a selective and qualitative process has been developed, related to the main parameters that influence on the definition of the different pneumatic typologies.

The reference sources have been the publications (books and technical articles) of the libraries which are described in the introduction; but also, the direct information by architects, engineers, manufacturers and tensile associations, about the pneumatic projects which they have developed.

4 DATABASE

The database has been build according with two main premises: It should be open source and interactive; in order to favor an active and flexible way to compile, organize and consult the documented projects.

The selection of the projects has been made according to qualitative conditions. In this way, the prototypes which are repeated n-times have been only taken one time into account. It has been only selected the projects that represent a qualitative difference between the others, with at least on one of the study parameters.

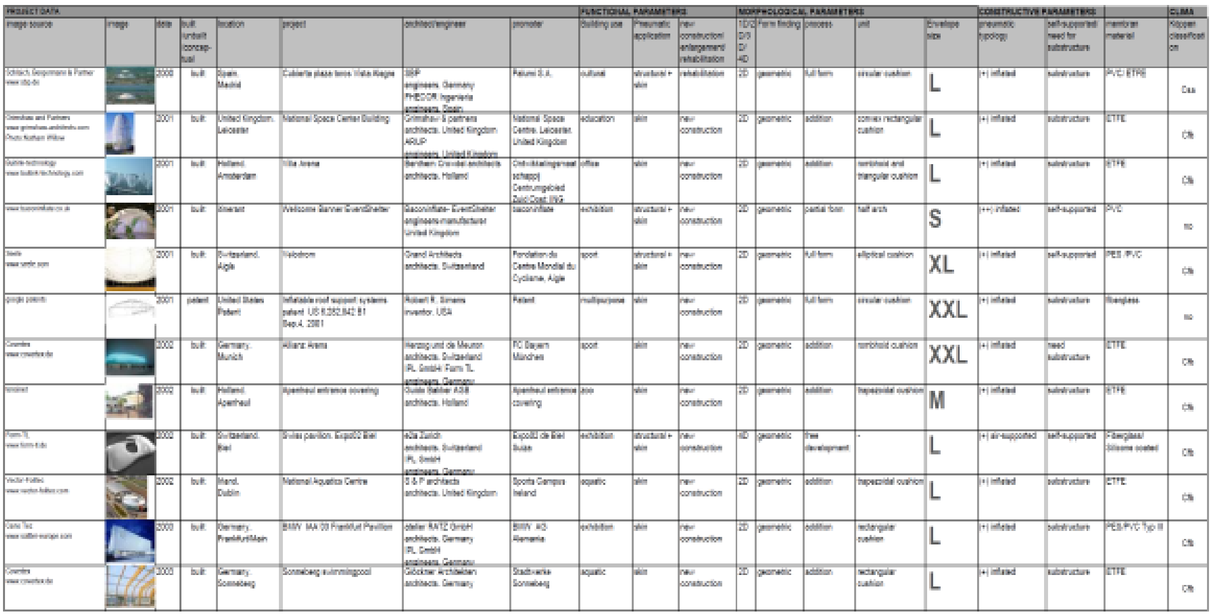

Figure 2: Compressed example of the database

The open source property helps the introduction of new projects, while the interactive characteristic allows the organization of the database according to each of the different parameters which have been defined. In this way, projects can be ordered chronological, morphological, climatic, functional, etc.; allowing the study and comparison of different type of projects in relation with independent issues.

The figure 2 shows an example of some projects compiled in the compressed database model. However, the main database is larger and it has been organized in the following 6 main parameters, further subdivided into their respective subcategories.

Contextual parameters
_Chronological study
_Location. City, Country
_Type of project. Built, in progress, non built, conceptual
_Author. Designer, promoter and manufacturer
Functional parameters
_Type of building use
_Type of pneumatic application
_New construction / Retrofitting / Enlargement
_Flexibility of use
Morphological parameters
_Main dimensions. 1D, 2D, 3D, 4D.
_Form finding
_Form of each unit, geometry and number
_Size of each unit and relation with the total envelope surface
_Types of morphological modification
Constructive parameters
_Pneumatic typology according to the pressure type
_Substructure typology and materials
_Type of anchoring
_Auxiliary reinforcements
_Type of membrane. Material and number of layers.
_Supporting gases
Climatic parameters
_Latitude
_Altitude
_Climatic zone
_Main climatic parameters: Temperature, humidity, rainfall, snow, solar radiance
Comfort and energy efficiency
_Thermal control
_Ventilation
_Natural lighting / shadowing
_Acoustic conditioning
_Solar energy integration
_Maintenance

4 SUMMARY FILE

In parallel to the main database, a summarized file has been developed in order to improve the particularized study of each project. It has been built a coordinated system of summary files, where the data of each project will be exposed in a more visual and easier representation. The relation between the database and the summary files has been optimized, so it is only necessary to select a project in the database, and their values will be automatically organized in the summary file.

While the database facilitate the catalogue and the comparative analysis between different strategies; the summary files allows the consultation of each project, individually, through the use of a simple interface.

Figure 3: Summary file

The figure 4 shows a zoom of a summary file, where are showed the different contextual parameters of one of the documented projects.

Figure 4: Zoom of the summary file

5 CONCLUSIONS

The research has allowed the qualitative definition of the pneumatic envelopes evolution, from the first patents to the present. Against the discontinuity of the publications and the specific thematic of current periodical publications; the selected methodology helps the compilation of great volume of proposals and gives continuity to the pneumatic systems state of the art.

A total amount of 663 projects have been documented, catalogued and analyzed; although the interactive properties of the database allow their increase, according to the approach of new proposals.

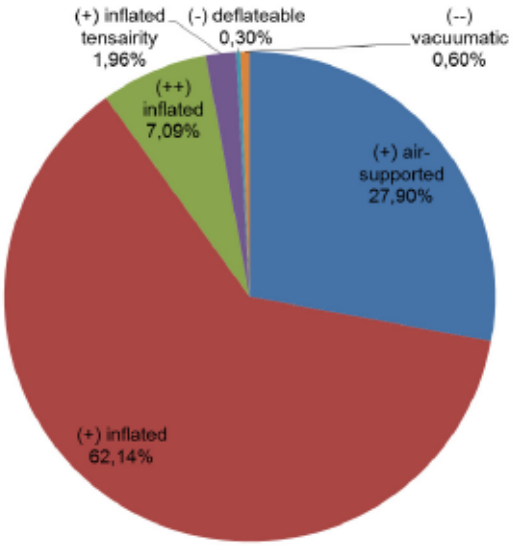

Figure 5: Percentage of projects documented, according to their typology

Also, the database has been developed to possibility the organization according to different analysis parameters (contextual, morphological, functional, constructive, climatic and comfort-energy efficiency); which helps the comparison between proposals, and the detailed study related to each parameter. This interrelated system will help to define the most relevant innovations and the new opportunity research areas of development.

In contrast with the static databases, the open source and interactive system favors the comparative and detailed analysis related to each of the typologies and parameters of study. Also, the design of the database allows an easy incorporation of new projects without modifying the previous values of other projects. In this way, it is possible to organize many different parameter classifications and their respective subcategories (contextual, functional, morphological, constructive, climatic and comfort-energy efficiency) in order to favor non linear and comparative analysis.

The relation between summary files and database allows the construction of an equal representation model for all the projects; which optimizes the data transmission and the organization of the consult.

The different projects have been analyzed according to each of the defined parameters, by determining the main problems and trends of this technology. As result, a new research line has been promoted with the objective of developing new strategies that improve this technology in the frame of sustainability.

ACKNOLEDGEMENTS

The authors would like to thank the Institute for Lightweight Structures and Conceptual Design (ILEK) of the University of Stuttgart and his researchers, for supporting the access to his library and installations.
Also the authors would like to thank the help and the information provided about projects and membrane-foil materials, by Bern Stimpfle of Form-TL; Markus Balz of SBP; Wolfgang Rudorf-Witrin of Ceno-Tec; Hubert Reite of Taiyo Europe; Robert Hodann of Nowofol; Karsten Moritz and Lars Schiemannn.

REFERENCES

[1] R. Dent, *Principles of pneumatic architecture,* Architectural Pr. (1971).
[2] T. Herzog, *Pneumatische Konstruktionen: Bauten aus Membranen und Luft*. Hatje (1976).
[3] K. Moritz, *ETFE film as a structural element,* TU München Dissertation (2007).
[4] W. Naumer, *Konstruieren mit Luft: Entwicklungen der pneumatischen*, Univ. Innsbuck Dissertation; (1999)