PARAMETRIC STRUCTURAL DESIGN

Mr. Jorge Farez  
Civil Engineer Profesor, Director of Research  
at the Department of Structural Design.,  
National University of La Plata (FAU UNLP),  
Buenos Aires Argentina.

Mr. Juan Fostel  
Architect Profesor, National University of La Plata  
Buenos Aires Argentina.

Mr. Patricio Lordella  
Architect Profesor, National University of La Plata  
Buenos Aires Argentina.

Abstract  
The present research describes the creation of an automated methodology of work using parametric modeling, combined with a structural analysis and the use of multi-purpose optimizers working as a tool for the exploration of a large design space, in the process of the decision-making and as an aid in the teaching process. The results obtained in this way show the exchange of information in real time between the parameters of the geometry of the objects and works of architecture and engineering. Fundamentally in the area of university education and conceptual teaching specifically in structures.

Topic: Research area Architecture engineering, Keywords: Parametric, Structural, Optimizers

CONTENTS  
1 Introduction.  
II Objectives.  
1) Work Team.  
III Methods  
A Energetic  
B Construction Impact
Has helped engineers and more recently architects to calculate complex structural models, allowing not only an accurate analysis of their operation, but also accelerating the process of obtaining analysis results, like deformation, stresses. Because classic engineering calculations involved in the analysis and evaluation are not integrated with the parameters of architectural design, evaluation takes place after the design is already defined, and analysis in real time is not possible.

II. OBJECTIVES
Development of a software tool, method of work and production in the design stage of architectural work; to optimize the structural design process to make better use of the energy consumed before, during and in the end of the useful life of the work in study. With application in professional and academic stages.

Our project team is made up of architects, engineers and programmers, allowing a multidisciplinary work, where we perform works currently under construction, in the area of research of the university Nacional de la Plata, we developed jointly with the teaching of our cathedra, new tools. (Fig.1-6)
This is the case of this paper is posed by the creation of structural optimizer that allows us to verify and analyze all the variables of a work and incorporating the priorities of the designer on each target.

II. METHODS
The present research describes the creation of an automated methodology of work using parametric modeling, combined with a structural analysis and the use of multi-purpose optimizers (Octopus Galápagos, zirkel) working as a tool for the exploration of a large design space, and as an aid in the process of the decision-making and in the teaching process.

Fig. 1 Floor Plan whit deformations
Building av. 38 – La Plata Buenos, Aires Argentina
Completed in 2016
1). Work team.

Fig. 2 view deformations
Parametricism term implies that all elements of the model are malleable, both in position and size, orientation, shape, color, constitution, etc, while all these elements are interrelated and an external influence that changes one alters all the rest. Therefore the object rather than a finished form, is the result of a certain number of parameters and functions programmed. All this is possible thanks to new advances in computing and information, before computational advance was unthinkable, so we are talking about a totally new method with no more than 10 years. In our discipline has endless utilities, it can be used both in research and in actual works.

A. Energetics

As previously mentioned, the construction of a work of great complexity you must take into account the analysis, the project, coordination of tasks, and implementation of the work, without neglecting the energy consumption this generates. Parametricism comes only to facilitate tasks but also to shorten work time, today there are BIM (Building Information Modeling) programs that provide a general overview of project, where any change in one of its stages can be automatically verified in the other, eliminating thus repetitive tasks that we do before manually editing the other stages (eg, whether we should change the dimensions of a column this probably changed the architectural plan, close carpentry, surface to revoke, etc. so it had to be modified at all levels and where have incidence scales).
Fig. 5 Facade Design using the algorithm Voronoi

That is why parametricism divides a big problem (architectural work) in many small problems working together, so you get more specific and effective global solutions in less search time. This line of research comes to ask, how can we create more efficient buildings? While it is a hot topic investigated usually sustainability analysis is done for a building is given the life of the building and the energy consumption of its use in that span. Our proposal is to find prior to use of the building solutions, so we began to analyze how we could optimize from their design process, using the optimizer multiobjective Zirkel. (Fig. 10 & Fig. 11) Thus avoiding unnecessary consumption of materials, and facilitating the architectural spatiality of the work. (Fig. 6)

This new design process will generate a reduction in shortterm costs for the investor, but will also reduce the long-term ecological footprint for future generations, marking a path of structural analysis and architectural optimization.

B. Construction Impact

As we know all economic sectors of society have a generally negative influence on the environment. The construction sector as we shall see in the following graph, is one that mostly affects the levels of environmental pollution, for this reason a while ago has been promulgating the building industry sustainability.

<table>
<thead>
<tr>
<th></th>
<th>Energy use</th>
<th>Raw materials</th>
<th>Water use</th>
<th>Floor</th>
<th>CO2 Emissions</th>
<th>Solid trash</th>
<th>Effluents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%</td>
<td>39%</td>
<td>20%</td>
<td>19%</td>
<td>30%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>43%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The construction materials affect the environment throughout their life cycle, from its first phase (removal of material) to the end of its useful life.
(treatment as waste), obviously going through all intermediate stages we will see then.
If all stages are added, the construction sector is the largest Ecological Footprint of our poses.
According to data of the United Nations, the construction contributes up to 30% in annual emissions of greenhouse gases, consumes up to 40% of energy, extracted a third of the materials of the natural environment, generates 40% of urban solid waste, consumes 12% of water possible and occupies 12% of the territory of the planet.
Moreover, economically it is responsible for 10% of world GDP (BENITE, 2011)
B. Optimizators
Every designer thinks parametrically, find the best balance between giving priority parameters which believes necessary, giving as a result a few models.
The parametric system seeks to solve the thought process allowing quickly modify the parameters and priorities, automatically giving greater number of possible outcomes.
The designer today has some interest in creating and scheduling of objects or tasks within the software, parametrically thinking, find the best balance between giving priority parameters which believes necessary, giving as a result a few models. (Fig. 7 - 8 - 9)
The parametric system seeks to solve the thought process allowing quickly modify the parameters and priorities, automatically giving greater number of possible outcomes.
Grasshopper is an algorithmic graphic editor related tools 3d Rhinoceros modeling, this open source program not only allows designers to create and program components, but also carry out multidisciplinary work where systems engineers configure specific features to facilitate analysis and processing tasks.
In the beginning of the project the parametric techniques allow energy analysis of structural behavior in general.
This approach is known as generative design, because through various algorithmic processes a form is generated according to established evaluation criteria.
The results must be validated by traditional analyzes to check the regulations and review its implementation.

Fig. 7 - COMPETITION : COURT COMPLEX IN NECOCHEA.
Studies for teaching students at Department of Structural Design.
Fig. 8 - COMPETITION : COURT COMPLEX IN NECOCHEA. 3RD PRIZE
Authors: Santinelli y Squillacioti, Parametric Structural Design: Farez, Fostel, Llordella

Fig. 9 - Deformation Analisis. COMPETITION : COURT COMPLEX IN NECOCHEA. 3RD PRIZE
Authors: Santinelli y Squillacioti, Parametric Structural Design: Farez, Fostel, Llordella

IV. ZIRKEL

Tool conceptual use for compression of structural performance developed and oriented universities particularly the Faculty of Architecture of La Plata, its use has been extended to professional practice as a preliminary to the final calculation with the use of multiobjective structural optimizers design.

Fig. 10 - Multi-objective structural optimizer
Zirkel compass (Fig. 10) is a multi-objective structural optimizer component build for Grasshopper with which you can search for possible result based on an unlimited amount of parameters and the goals are limited only by the complexity of the graphics generated by te computer. (the latter still in development).

This developed entirely in C # .Net with Grasshopper own libraries, so that it can interpret it, and a library called 'HelixToolkit' with which it could develop 3D graphical environment.

As the graph is an area in polar coordinates which is divided according to the number of objectives, which are sought as they approach another target areas are stained 2 colors and are no longer pure in color

Finally chart below is a comparator (Fig 11.) which compares one by one the objectives and the button located below the comparator can display each result in the environment Rhinoceros and Grasshopper.

This works as an assistant in the process of selection decision when the optimizator show a lot’s of solutions.
C. Teaching

This novel way of teaching (Fig. 12 - 13 -14) apply for 3 years in college and in the course Estrutural Graduate Design dictate in Department of Structural Design. of National University of Architecture and town planning. La Plata (FAU UNLP), Buenos Aires Argentina.

Studies for teaching students at Department of Structural Design.

Fig. 12 - Bus Station in Casar de Cáceres, Spain / Justo García Rubio

V. CONCLUSIONS

The results of this research describe work methods and methods to evaluate alternative design proposals at an early stage in real time. An architectural form not only can be analyzed on the basis of their structural behavior, but it can be derived through the process of structural simulations.

The results of this research describe work methods and methods to evaluate alternative design proposals at an early stage in real time. An architectural form not only can be analyzed on the basis of their structural behavior, but it can be derived through the process of structural simulations.
ACKNOWLEDGMENTS.

- School of Computing National University
- Faculty Of Arquitectura and town planning. National University of La Plata (FAU UNLP), Buenos Aires Argentina.
- Preisinger - Clemens consultant for issues with Karamba
- David Rutten consultant for Grasshopper components.

REFERENCES.