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CALIBRATION THE TERM OF STRUCTURAL CONSTRUCTION BY A NEW WORKFLOW IN USING DIGITAL ENVIRONMENTS

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ABSTRACT

Missing the exactly stress-based evaluation in structural design have been turned problematic depends on the lack of using powerful tools both in estimation and construction. With the ability of digital tools some difficulties have been passed; but yet there are not fully modified workflows of structural evaluation and construction in relation to the digi-tal word. The article is aiming to introduce a new workflow for adding digi-tal structural evaluation-and next digital structural construction-to the cur-rent design processes for calibration of structural estimating.

Keywords: *Structural evaluation, stress-based evaluation, digital tools.*

INTRODUCTION

The original nature of Computer Aided Design (CAD) systems, introduced many years ago, was referring to a kind of geometric description of ele-ments to produce a presentation of the architectural conceptual design. Such CAD systems did not have any capabilities to behave like the real world in containing properties, causing problems for designers. Some of the most important ones, was that a lengthy and costly way for producing documentations, the lack of ability in changing (changing was referred to remodeling) and less intelligence in modeling that was forcing the designer to particularize any part of design by him/her self (Schodek et Al., 2005). From the demand of design professions and based on adding real world state to digital modeling, CAD systems has been evolved from pure geo-metric representations, to the representation of "information", in general, or properties, relationships and behaviors, in specific (Kloft, 2006; Kym-mell, 2008). This field of adding information, which is finding broadly in Building Information Modeling (BIM), is an area of interest (Chaszar et Al., 2006) because of its capabilities in representing ever growing information in digital architectural or structural design.

Parameter, is a mathematical based concept that represents the Latin words, para which means "beside" plus "metron" which shows the con-cept of "measure", referring to any value or measurement that is some-thing else depends, and commonly refers to variables in mathematics, that are part of a domain and can be altered in a function to produce a new value going out, replacing the old ones (Cárdenas, 2007). Parametric de-sign is an idea based on the notion of parameter, introducing a design ap-proach that within that, the concept of design easily can be parameter-dependent; representing a family of forms based on the

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original, through a digital modeling of the project. This kind of variation although something likes the first model, developing designer ability in orders to test several alternatives of design. Despite BIM, parametric modeling developed not on designers' demands but based on industry needs, through the process of production, to man-age several relationships among parts in a specific machine. In other words, the necessary need of product integration between design and production resulted in development of such systems with the great capa-bility in altering and changing, accompanying increasing flexibility and re-ducing waste. Based on this history, the term Design Developer Environ-ment (DDE) has been introduced, in order to configure and to represent parameters in design. Design Developer Environments usually have a hier-archical structure to prevent remodeling by saving previously applied ac-tions to the model.

THE CURRENT SITUATION OF EVALUATION IN STRUCTURAL DESIGN AND THE POSSIBILITIES OF DIGITAL ENVIRONMENTS

The approximately situation of current structural design

During the old history of structural evaluation, almost all structural meth-ods have contained some kinds of approximately estimation. In a usual life of structural designers, for instance deciding about a slab structure of a building exactly depends on some kinds of abstraction in calculations. In other words, the calculations not contain details about the whole stresses in the slab but altered within main stress guidelines. Although these calcu-lations are enough for problem solving, but they are causing material waste depends on their approximately situation. Based on available digital tools, it looks like that the current capabilities of digital environments including Computer Aided Design-in soft ware-or Computer Aided Manufacturing-in hard ware- are the new and calibrated ways for passing these approximately calculations (Schodek et Al., 2005; Chaszar et Al., 2006).

Possibilities of digital soft-ware environments in current structural design methods

In the space of soft-ware, it is clear that passing the design from any digital design environment without having a defined strategic approach to mod-eling becomes problematic as different capabilities of the digital environ-ment could become useless and applying any changes to the design would be costly and a time-consuming remodeling. Depending on this criterion, the strategic approach to modeling is the main part of any design prepara-tion for digital modeling environment, including various kinds of software (Cárdenas, 2007).

Focusing on BIM and DDE, as two main important digital design environ-ments is the main provision for the articles proposes based on their neces-sity for the workflow which will be introduced later. Following some of their properties and limitations will be mentioned.

Many of current BIM environments have been limited to the boundaries of quantitative information, ignoring quality, property and relationships. Ignoring the broad potentiality of producing a fully parametric model is the other limitation in these environments (Lally, 2007). Based on what men-tioned earlier, it is obvious that ignoring multilateral use of parameters re-sults in limitations in design variables and having less geometric altering.

On the other hand, Design Development Environments have a hierarchical structure that allow saving the history of actions, powering the easy alter-ing and change without re-doing. Also, the ability of feature-basing ena-bles the detailed representation of complex objects, preparing the ability of integration of multi disciplines in a unique design project (Chaszar et Al., 2006).

Detailed refinements of components take advantage of parametric capabilities to create families of shapes; something which allow develop-ment of design alternatives, gathering a field for customization (Leder-mann et Al., 2005). Knowing this spot is necessary and obvious that the ca-pabilities of Design Development Environments in parametric modeling is more developed and defined in relation to BIM.

Possibilities of digital hard-ware environments in current structural design methods

But in hard-ware world, there are lots of current machines that enable various structural designs to become real. Indeed, the existing industry-based materials that being used in structures have been shaped by ap-proximated methods of calculations. For instance, the dimensions of beams or columns in a steel structure, depends on the steel table of a steel provider or a steel industry; in other words, there is no intermediate line for some kinds of detailed calculations that are not matching on the steel table.

Current advantages of using industrial machines in the building's field, en-ables designer to more accurate and calibrate the construction phase with the demanded design criteria including various kinds of formation. In brief the existing methods in digital machines divide to 3 main categories, in-cluding: additive (connections, fastening and fabrication), subtractive (ma-terial removal) and transformative (deformation, molding and casting).

THE WORKFLOW/PROCESS OF CALIBRATION THE EVALUATION IN BUILDING DESIGN DEVELOPMENT AND CONSTRUCTION PHASE

As mentioned earlier, the quality is the missing part of the current digital design development process. In order to add quality to design, and based on the existing literature, the aim of this article is to compose available ca-pabilities of mentioned tools (current tools in the field of digital design), to produce a structure for digital design development period, looking for the best structural estimation and relying on the digital construction methods. It is notable that here the best is not at the absolute meaning of it but re-ferring to the design developer (human or machine) possibilities.

Some simpler cases can be found in literature (Ledermann et Al., 2005; Aizhu et Al., 2006; Mueller, 2006; Cárdenas, 2007) that assisting the confir-mation of proposed workflow, but the same as the structure of workflow has not introduced yet. The proposed structure has 7 main stages that can be find in following chart.

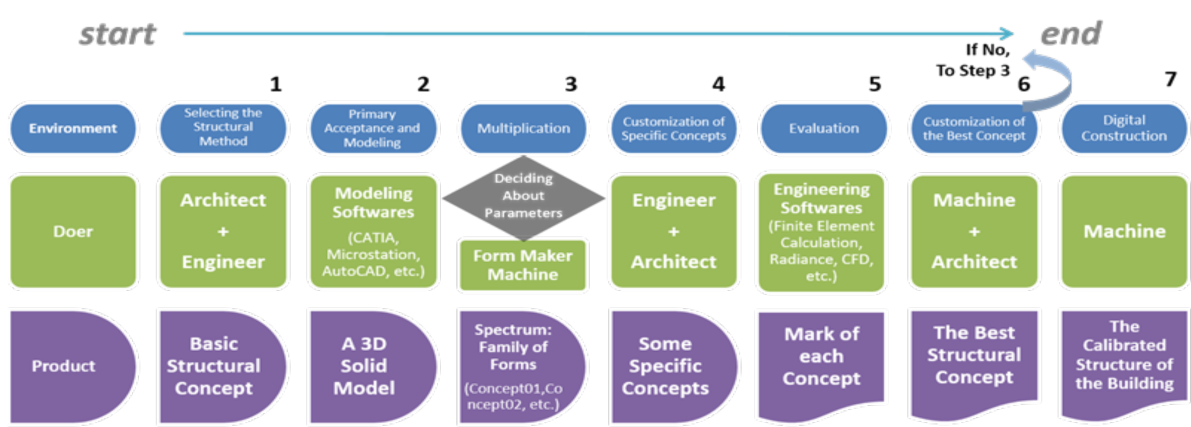

Figure 1. The design workflow/process of calibration the structural evaluation.

DESCRIPTION OF SEPTEMPARTITE-STAGED WORKFLOW/PROCESS

During an overall view on the workflow/process, the process is subdivided to seven relational stages that each depends on past stage. The work-flow/process will be described in detail to illuminate some sophisticated or abstruse points.

i. The starting stage which was called *selecting the structural method*, referring to inquires on producing primary design concept, which originally being done by *architect* with a key role of structural engineer consults. Totally the outgoing product of this stage is the *basic structural concept.*

ii. Focusing on the second stage (*primary acceptance and modeling*) the architectural team deciding about the feasibility of the concept in a fully abstracted method. If the preferred concept from the first stage accepted by the design team the concept will be introduced to various modeling software-including some design developers or BIMs-for production of a *solid model.* Features of this stage are: First it is the importance of revenue from a shared decision-making team (including designer, contractor and construction observer) specifically at *early stages* of design. The importance of the idea has been confirmed broadly by design professions, as ignoring that will result the lack of shared and original perception of the project; leading to missing the concept among designer, contractor and so on. The second point is the choice of solid modeling for digital 3D presentation, depending on some powerful abilities of solid modeling in relation to preparation of concept for digital evaluations. In detail, there are broad capabilities for digital solid modeling despite of-surface modeling- which will enable sophisticated numeric calculations on the model. The necessity of this ability become obvious when the design development phase needs some kinds of important numeric evaluations-for instance large scale CFD calculations about a structure. Also, most of design development environments can use their whole capabilities on solid models. In addition, the last important point on the stage is the confirmation on the original role of architectural designer as a real creator. Based on current literature there are some arguments on computer's digital-form-making as an original architectural method. To reduce the impact of computer on concept, here, the workflow is not considering any role about computational form making to save original flavor of the concept, but on the other hand, it concerning on development of the design development phase by broadly using of powerfulness of digital tools demanding more variable alternatives in the phase.

iii. The third stage is *multiplication*, following a kind of verity on basic concept. As it has been presented, the end target of the stage is to multiply basic concept simply by a multiplayer, to prepare a family of forms (a spectrum) that each are same as the original concept but with a little difference on its parameters. In consequence, each concept from the family coincidentally is same as original and is different from the other family members. This strange ability has been rooted in the potential of parametric design. In other words, if the design team produces a parametric digital model of the concept, the easy step would be the change in parameters-by altering figures in relation to changing numbers in parametric system. During the process, verity of shapes same as the original concept will be produced. Although the process of making a family of forms-based on design development environments capabilities-have a long history in the field of industry-as mentioned earlier-and currently it has been limited to the change of quantitative parameters and relationships-for instance dimensional parameters of an industrial part- but here the character of *family of forms* is the preparation for evaluation phase and has not been considered an original role for it. Same as other parametric variations, here the most important activity is the definition of parameters and their dependencies in a fully hierarchical structure for prevention of remodeling. Indeed, the more parameters, the more flexibility in alternatives; but on the other hand, the less parameters, the easier and less time-consuming management of hierarchical structure. Also, definition of parameters must prevent from over-parametric situations which results miss conception. In order to pass the sophisticated period of defining parameters, here are some discussions. Some of them concerning on pre-defined parameters; for instance, they are following preparation an external domain that has been built on the accepted criteria of designer. These fundamental criteria can have alternatives from knowledge-based criteria, scientific criteria, Structure or Building Code criteria and so on. On the other hand, other discussions concerning on receiving user/designer criteria through an interactive method that suggest some choices to designer and define parameters in relation to his/her responses. Because of the originality of discussions in the field of management a design processes the article will accept the definition of parameters without detailed description of its methods.

iv. As parametric modeling can produce uncountable alternatives, and because of the limited potential of computers to calculate countless alternatives, at the fourth stage, *customization of specific concepts*, the designer and engineer-again as the only actors-will search the spectrum to find which specific concepts-the number of concepts depends on the power of provided evaluating computers- is more different or has more changes in shape n relation to others. This kind of selection that refers to the limitation on computers, although ignoring some parts of spectrum, but with the selection criteria of *more difference*, surly impact the most important points of the spectrum, forbearingly cover the whole spectrum. The output of the stage is some specific concepts from the uncountable spectrum.

v. The fifth stage, *evaluation*, is the environment of evaluating customized concepts in evaluating software often based on numerical calculation (on a solid model). At this stage, the design team preparing the specified concepts-for instance 50 from billions-through the evaluating software(s), to mark each concept. It is obvious that selecting a solid modeling strategy at early stages, enables the designer and evaluators to make more facile dialogues because of the same modeling strategy on using solid models. Kinds of evaluation depend on the necessity of them in the structural design. Various kinds from stress investigations within a finite-element method to the calculation of the effect of arrangement of structural components on material waste, to the foresight and investigation of fire spread in the structural components and their best location in reduction the fire speed, all can be obtained through these powerful evaluation tools. At the end of this stage, the designer/computer will mark each concept by their records in such experiments, depending on the importance and weight of each experiment in the evaluation of the project. The total score of any concepts will be prepared by the multiplication of each record with the value or weight of the experiment in the project (see: Golabchi, 2007). These values can be numerical.

vi. The sixth stage is the *customization of the best concept*, referring to a choice among selected concepts depends on their scores. Clearly, the best concept has been achieved. It is necessary implying here that the term *the best*, as mentioned earlier is in relation to numeric qualities. So, it nor has been followed, neither feasible (in some arguments) evaluating something like aesthetics in a digital process.

vii. The last stage called *Digital Construction*. In this stage the calibrated structural design that extracted from the process-based on the ability of digital finite-element calculations-will be introduced to digital machines. Using digital tools in the stage is in order to be responsible about the sophisticated calculations that will not mach on the specified existing construction components in the market. Here, based on what mentioned about the verity of digital production tools there are various industrial and digital methods.

APPLYING THE METHOD ON A CASE

Depending on introduced structure, there are many advantages in struc-tural calculations based on the abilities in digital machines. For instance, if there is a subject in structural design of a slab, based on the work-flow/process there are seven consecutive stages. First is the deciding about the concept of slab's structure-for example: multi-directional beams, space frame or etc. - based on the main idea of design creator. The second phase is the confirmation of the method by simulating the model in digital design environments-soft ware. The main output of the stage is a 3D model with the capabilities of solid modeling; here the capability of numerical calculations. The third stage in the case is the multiplication of the concept of structural form by assigning parameters in it. The output of this stage will be a family of solutions and forms within a specific structural method; for instance, if the selected structural concept is waffling slab and the parameters are the dimensions of a single cell of waffle, the spectrum is lots of waffle slabs with different dimensions in length and width of cells. As this spectrum is uncountable, in the fourth stage the designer cus-tomizing some specific form– among the family- that is more different from others. In the next stage, these specific concepts will be calculated within digital evaluations for comparison. In fact, based on the solid mod-eling-that has been used in workflow- here is the ability for finite-element calculations about the structural design. This finite and particularized method is a useful help for calibration of structural calculations and results in more accurate consideration of the value and position of stresses in the slab. After the valuation of specific concepts, there are some marks for each concept depending on the–architectural or structural-designer in the end of fifth stage. In the sixth stage, the marks are determiners of the best concept. During the last stage, the best structural concept will be held in construction period depending on the abilities of digital machine; in cur-rent example by a not so difficult production of some mold for waffle slab-by making a negative mold within a subtractive CNC machine-which they have been not in market yet.

CONCLUSIONS

By the structure described above, the important point of the work-flow/process, is the achievement of the best concept; at first it is same as the original concept and has its flavor-so the designer ideas is not ignored or missed during the process- and at the same time it is –not absolutely but as possibilities- the best concept in relation to numeric variables and values like having better stress passing, less material waste and etc. the importance of saving the designer originality become more obvious when knowing some arguments that abandon the whole powerful and useful process in digital modeling, decision making and evaluating because of the saving of designer originalities.

Other researches and inquiries can follow making clearer some points in the process such as making decisions about the methods of parameters' defining. Others can clarify the exact role of design team members, includ-ing architectural designer, structural designer, contractor, supervisors and observers, design controllers and evaluators etc. in the process and locat-ing them in some specific situations.

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