Structural modeling: choices, uncertainties and… decisions

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ABSTRACT

During the process of structural designing for a building to be developed, as well as during the check-up of the structural integrity for an existing building or for a building that has undergone different interventions, assumes first of all, an accurate and precise structural model for the building design, through an accurate study.

This accurate study, prior to the design process, should take place and a multitude of different factors and criterions need to be taken into consideration, starting from the materials that will be used, their way of production, typology, shape, dimensions, and installation.

The study can than move to an accurate analysis of how the structural elements will be linked together, where the structure will be laid, how long will the building be used for.

The study can end with the consideration and analysis of the maintenance and possible future alterations and/or interventions during all the life of the building.

Keywords: *Structure, system, design, calculation, construction, modeling.*

INTRODUCTION

Whenever we are faced with a planning application for a new building or when we are faced with the evaluation of an existing building and interventions or changes to be made, we will idealize that building in a form from us understandable as well as practically computable.

Through this process of idealization, really for a "yet to be built" building, we need and there is in front of us the demand to conceive and create a model:

- similar to the object and / or intervention to be implemented;
- representative of its behavior in each of its parts and/or of the whole structure as well, under different and various loads and situations;
- representative of its implementation, the applied technologies and materials used;
- etc...

Subsequently, applying at this model certain formulas - even themselves by a side function of the model itself and by the other side functions of the respective theory and the calculation method which is in use - through numerical calculations, we will try to find and to obtain a solution which then should be carried out concretely.

Thus, simplifying, we can outline the steps to follow for the creation of a model for the design, for example of a new building or an intervention in an existing building, as below:

1. Initially goes imagined an object "as possible" similar to the building or the additional work required;

2. Then, we trying to choose the materials and technology of the possible implementation of the various elements and parts of the object;
3. In relation to these first two first choices, we will decide for the load-bearing structure, which should ensure the strength and resistance of the object as well as the respect of its functionality;
4. Over this structure we have to applied shapes and sizes, even they themselves functions of all previous choices;
5. The forms and sizes as above will give the load values, as well as the behavior of the structure under their action during the time;
6. At the same moment and with the same limitations and influences, on the structure elements should be applied loads and external actions, always connected, and employees of all previous choices;

Figure 1 Realistic structure and its idealization model

Later we schematizing the main steps to follow for the calculation, as below:

7. Choosing first the method of calculating such as whether 2D or 3C, whether static or dynamic, etc .;
8. Than choosing the degree of numerical precision in the calculations to be carried out, etc .;
9. At list, choosing the software or use program for the specific calculation, etc ..

As you see, there are many unknowns choices that we have to make and, most importantly, every choice leads and involves respective restrictions, errors, inaccuracies. And this not only in general, as can be seen from the schematically represented above, but also in every aspect of the design.

So, without trying to give definitive answers and solutions to the many problems and uncertainties, we will try to treat some of lots of cases, that generally arise and offer possible choices or factors to keep in mind while trying to decide for the one or another model.

BUILDING MODEL BETTER THAN THE STRUCTURE ONE

Always, when we are in front of the design, the idealization of the work in a model, we think to present it as an idealization of a BEARING STRUCTURE MODEL.

And needless to say that, even in light of as above briefly described, idealize the whole building modeling only the structural part of it, is very limiting and predisposed to many inaccuracies.

The bearing structure is only a fraction of the entire building, which later would be charged with all the other parts and components, as the walls, installations, etc ..

Parts and components which, through their links with the same structure, will also influence the behavior and structural response of the chosen model.

But not only.

In the design objects - for example a residential building as well as an industrial building, a bridge or another one - for its normal operation, will be applied and positioned installations of different importance, but that in any case, always will influence the behavior and structural response of the chosen model.

Let see this, for example, throw a "simple" truss model, as above:

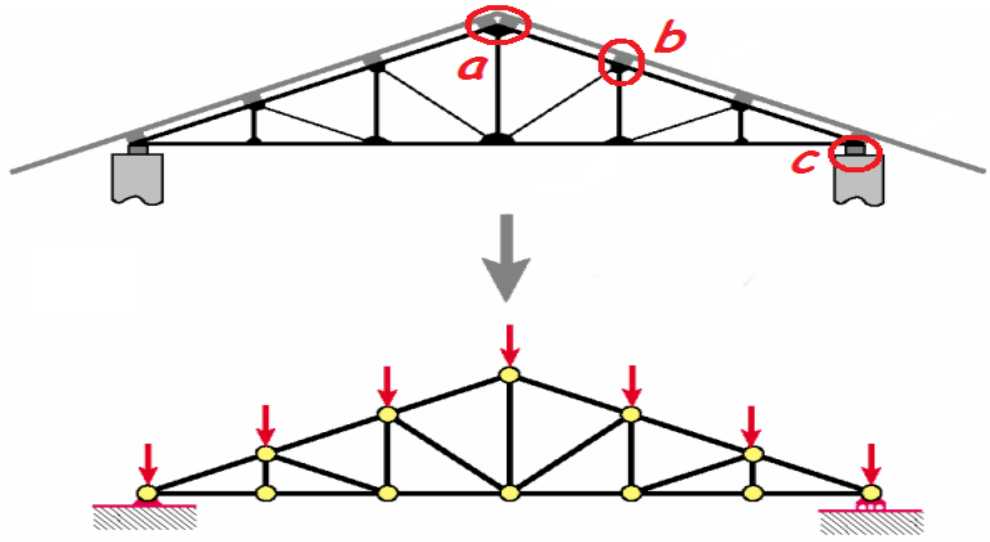


Figure 2 Roof structure and its idealization model

As we can see, in shaping all nodes as perfect hinges, we "lose" or we did not take into account the real influence of the cover and the fixing way of its elements, highlighted with a) and b), which actually change the behavior and reaction of the truss under the loads of the same elements as well as under other loads and actions.

The same, in shaping the supports as perfect fixed or free hinges, we "lose" or we do not take into account the real influence of the support throw its adherence, etc., marked with c), which in reality will change the behavior and the action of the truss under the appropriate loads as well as under other loads and actions. And not only. It will also change the distribution and the value of reactions of the structure over its supports.

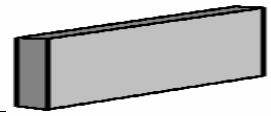
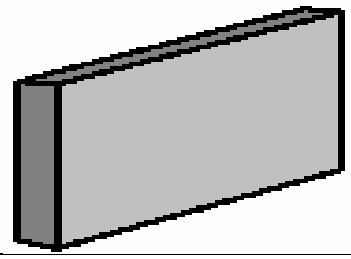
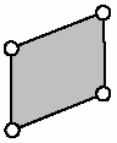
Therefore, in conclusion, we think that in carrying out the design, in place of the idealization of a single MODEL STRUCTURE, we have to try to devise a whole OBJECT MODEL - BUILDING to achieve.

MODELING OF THE STRUCTURAL ELEMENTS

For the next part of the numerical calculations, it seems normal and generally accepted the fact of the "replacement" of the various structural elements through the idealization in different structural models.

Thus, for simplification of the treatment, we will consider only three items as below and then we try to present the uncertainties of the factors at joke, and their influence in subsequent evaluations and results.

Table 1 Element and its possible schematization

	Real element		Schematization
A		metal beam	
B		wooden beam, brick, r.c. or other	
C		wood wall, masonry, r.c. or other	

The first case, this one of a metal beam, may be the more simple and with less uncertainty. So, not wanting to take into account secondary and additional effects connected with thicknesses, heights, relations between souls walls and lintels, etc., we can say that the schematic choose will not represent many uncertainties, errors and/or inaccuracies in the calculations and results.

But everything changes evaluating the two subsequent cases, B and C.

Thus, the acceptance of the first or of the second schematization, will be with more or less uncertainties or errors, on the function of the used material, of the direction of its fibers or of the laying of the concrete, of the size and composition of the joints, etc...

But not only. The same schematization will depend also by the sections dimensions, height or width, as well as from their rapport, etc...

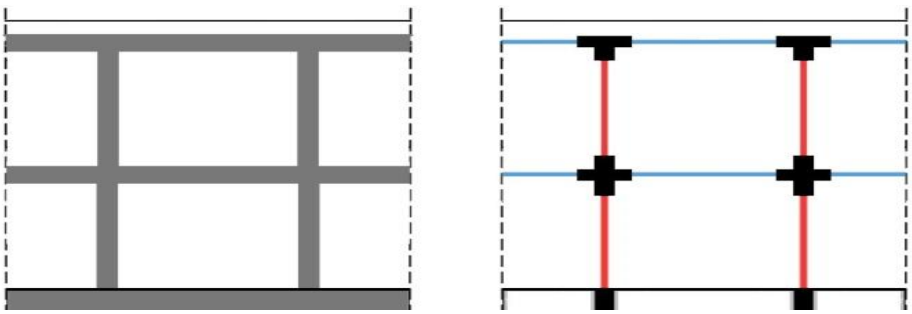


Figure 3 Connecting nodes of beams and columns

And what can be said then for other elements "compounds", for example the connecting nodes of beams and columns, etc.?

In such a case, the extension of the "rigid console" that is schematizing the same node, it should be taken equal to or greater than the beam height and the pillar width?

And this value should range or not, and to what rapport, also in light of the fact that the node is the final or intermediate one?

And this value should range or not, and to what rapport, as function also of the width of the beam and the pillar?

Therefore, in conclusion, we think that in carrying out the design, one or other of the schematic elements as above, should be determined after several assumptions and comparison of their results, as numerical or as structural behavior.

SLABS MODEL

The practical realization of the floors varies by their type and type of the elements, by the direction and positioning of the joists as load-bearing elements and complementary elements, by the ceiling height, by the presence and thickness of the subsequent r.c. jet, etc ..

The above may be similar or may vary from one covered field to another one.

Bearing in mind that as above has influence and "decides" the deformation and the uniform movement of the structure, we can understand how important is the idealization of the model chosen as a representative of this part of structure in subsequent calculations and final numerical results.

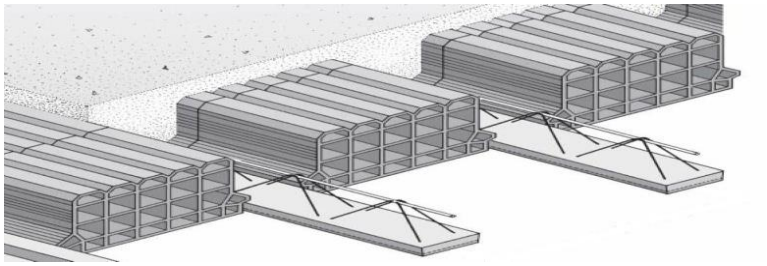


Figure 4 Connecting nodes of beams and columns

So, we can say that a "light" horizontal structure will fail to operate as a real "horizontal rigid connection", so that pillars and other vertical structural elements, will not move “altogether” but independently and differently one from each other.

The same, if the slab would be textured entirely in one or other direction, the structure will deformed uniformly under the action of loads acting normally to such texture, but the structure will not deform uniformly under the action of loads acting parallel to this texture.

Furthermore, the above would be a little less certain in the case of very extensive slabs, or of slabs with strong indentations, etc...

Therefore, in conclusion, we think that in carrying out the design, final schematic of the slab should be decided after a long evaluation of effects as above and others, or after several attempts to calculate with free "slave" nodes and without "master node" .

Only later, once assessed and met the real "behavior" of this part of the structure, through identification of areas with similar behavior, we can go in the application of one or more master nodes.

WALLS AND timbers MODELING

In the case of treating load-bearing masonry, normally we can recognized a well idealization structural model. Instead, in the r. c. structures, where the supporting structure is composed of frames or r. c. walls, it is denied the role and influence of the walls and timbers in the behavior of the entire building.

By the way, these “parts”, the walls and timbers on the r. c. structures, are called “not structural parts”, when in fact their influence is of great important and goes beyond their “dead loads”. So, their influence consists both in charging structural elements as well as on changing the behavior and response of horizontal or vertical structural elements, such as floor slabs, beams, etc., pillars, r. c. walls, etc...

But not only. In addition to changing that behavior, often the walls and timbers act against those others structural elements, causing on them structural damage, changing definitely the reaction and behavior of the entire structure.

The walls and timbers influence also is depending by the facts that:

- they are develop for the whole height of until the top or only up to a certain height;
- they have or not holes, openings or other, such as doors, windows, etc., of varying shape, size and positions;
- they are positioned in axis with pillars or other, and are linked or not with them, etc...

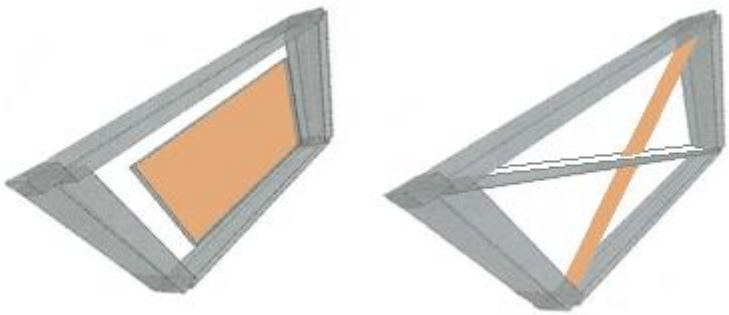


Figure 5 Timbers to braced frame

Even in cases when we accept to consider such influence simply, only through the “compression diagonal connections”, we will face the uncertainties of the characteristic values of the real strength of the walls, etc.

Perhaps it will be better to idealizing the influence of masonry throw the “compression diagonal connections” as well as throw the “tensional ones”; at least for the first time and until the masonry completely lose its ties offered by the mortar. Certainly that, this choice, theoretically more correct, will add and multiply the unknowns in joke.

Therefore, in conclusion, we think that, bearing in mind the large number of unknowns as above, it would be better to choose two different "roads":

- Add structural metallic elements, like contra forces, well known and identified, and subsequently consider their contribution;
- Completely eliminate the possibility of the influence of the walls and timbers on the supporting structure, by insulation throw realization of the parts with "plastic" characteristics along all their contact surfaces, as well as in the corners of the masonry walls.

NEAR OBJECTS MODEL

Another issue to consider can be the case of objects that, even if not connected "firmly", are near one with another or that are just in contact with one another.

In this case we can say that the problem would occur until, under the influence of horizontal loads, such objects would seek only to get away from each other.

But we can not say the same in the presence of seismic action. Under this action, the objects, for example two contiguous buildings, too close, not connected but only in contact with one another, hammering each other, with structural damage and also with changes in the response and behavior of the same buildings.

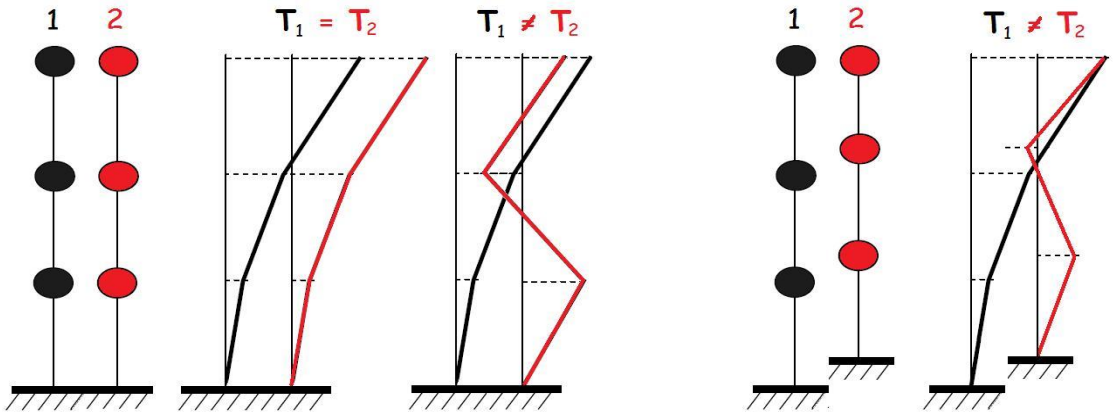


Figure 6 Behavior of buildings with similar or different characteristics

Idealization of the respective calculation models, there would be different influencing factors to keep in mind, such as:

- The two buildings have the same overall height and start from the same level of the 1st Floor;
- The two buildings have equal levels heights or their slabs are “out of phase” with each other;
- The two buildings are placed on similar / same or different terrain, etc...

Simplifying the respective conclusion, we think that the effects of hammering can be more serious when:

- The buildings periods will be very different;
- They starts at different levels of the 1st Floor;
- They have different heights for the planes, such that the slabs may hammering the pillars along their height and not in correspondence of the respective slabs;
- They are placed on different terrains, which would change the characteristics of the respective seismic action, etc...

NORMAL AND/OR AGILE TRATEMENT

Another argument, which we are thinking about, is the way chosen to treat the entire idealization process of modeling.

The whole process could be treated in a "Normal" or "Classical" way, where from the beginning we choice each topics and parameters, as building's plant, the type of the main material used for its construction and completion, the type of structure, the shape of the sections, etc., and keep everything unchanged until the completion of calculations and designs, or doing only some essential corrections if required by the recommendations of the Technical Standards.

However, bearing in mind the wheel of factors and uncertainties in play, their "individual behavior" and moreover their behavior in the set of combinations and inter-influences, etc., we can feel almost impossible to have at the end of entire process of modeling and calculating the optimal results or the best one possible.

This because of the very rapid progress and change of technology, material productions, way of realization, conditions, materials, characteristics, etc..

For this, a better way for the treatment of the entire process under discussion may be to pass in the choice of the data for each variant, step by step, during intervenes in the different phases of the design process of modeling.

The above could be represented as below:

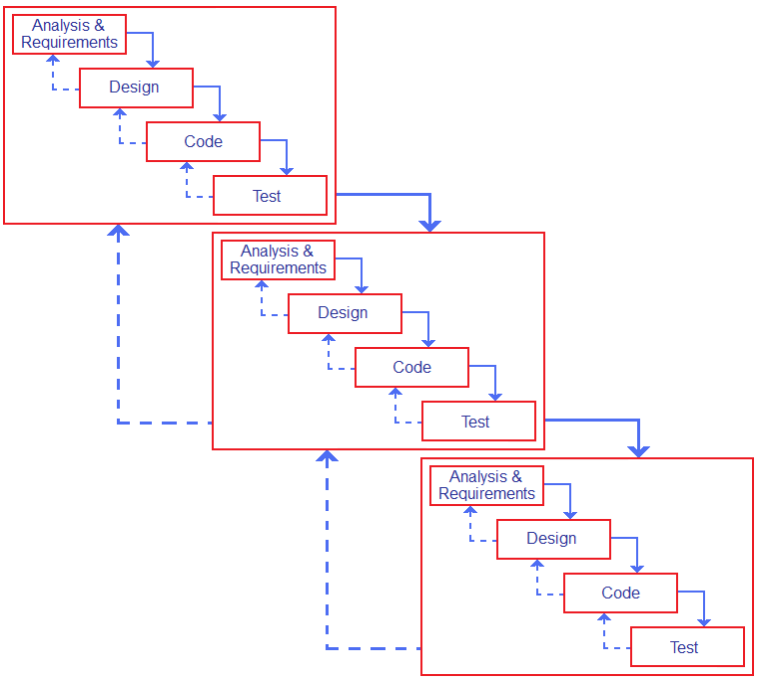


Figure 7 Design-Code-Test iterations (de Weck, & Lyneis 2011)

In conclusion we can say that passing from a "Normal method" at the "Agile method" for the entire idealizing of modeling process, we will allows to:

- Take advantage of what was learned during earlier development in later iterations.
- Focus on short term objectives.

CONCLUSION

Having tried to present possible conclusions for each case treated as above, we only will again highlight the fact that there are so many unknowns and uncertainties to be addressed and considered in the process of idealization of modeling objects to design.

For this, the choice of the respective definitive model, must come from the comparisons of the many models with different initial assumptions, through evaluation of results both quantitatively and qualitatively even more.

Besides all this, we think that, from the very first steps of the model idealization until the complete realization of the buildings, these assessments and choices could not and should not be make alone by the architect or by the designer, but throw a continued true and real collaboration, between the Architect, the Designer and the Project Manager as well.

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