A concerted and multi-criterion approach for helping to choose a Structure-Foundation system of building.

Summary.

The research of the best building design requires a concerted design approach of both structure and foundation. Our work is an application of this approach. Our objective is also to create an interactive tool, which will be able to define, at the early design stages, the orientations of structure and foundation systems that satisfy as well as possible the client and the architect. If the concerns of these two actors are primarily technical and economical, they also wish to apprehend the environmental and social dimensions of their projects. Thus, this approach bases on alternative studies and on a multi-criterion analysis. In this paper, we present the context of our work, the problem formulation, which allows a concerted design of Structure and Foundation systems and the feasible solutions identifying process.

Keywords: Early design stage, building, foundation, multi-criterion analysis, decision making.

1-Context.

The building can be generally subdivided into several subsystems (foundations, structure, envelop, etc.). Buildings represent a complex assembly of many different systems such as the enclosure, structure and ventilation systems [Meniru et al 03]. These subsystems are strongly dependent between them by physical or functional relations and their definition develops during the different design stages. Moreover, several actors take part in the design of each subsystem and every one of these actors has different points of view. So, these are the multi-techniques and multi-actors aspects according to [Mangin,99]. For example: the point of view of the building stability is collected by the client (required safety and comfort level), the architect (architectural creation and spaces organization), the engineer (structure design), the geotechnical expert (soil study and proposal of the best foundation system), the enterprise (building realization). These actors can sometimes have contradictory interests (ex: the choice of structure with concrete walls forces the architect to limit the openings choices (doors, windows, etc.) that he wishes to create. But this choice is preferred by the geotechnical engineer if it is necessary to stiffen the structure). Also, we need a collective approval on the various project aspects. But in practice, it is rare to be able to make work the various actors simultaneously, because according to [Mangin,99], the most frequent practices of design-realization take place in a sequential activities (Figure 1). This fact does not favor the information exchange and generates major communication problems between the construction actors [PCA/PIRTTEM, 93].

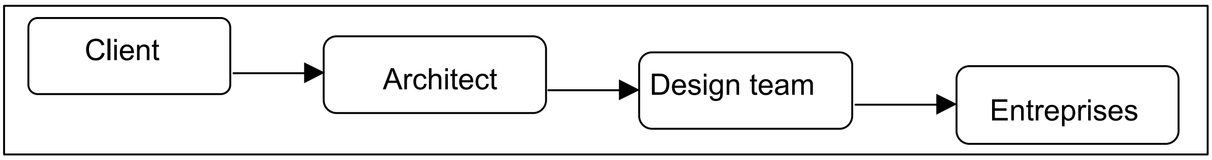

Fig. 1 : sequential chain of design-realization tasks

To favor the exchanges and to allow a collective approval on the various project aspects, there are two ways:

- The first way depends on a new organization in the project structure, by integrating principal project actors in early design stages [Sahnouni, 99]. So, the co-operation needs to blame the tasks chain of design-realization, witch is usually sequential and to meet actors and to agree their role. This reflection way requires to engage all building partners, but it is difficult to put into practice because the project presents a competition between the actors, who wish to cooperate while keeping a hegemony, even partial, on the project.

- The second way, where we position, relates to the project instrumentation. The goal is to model the data and the processes in the building design-realization cycle, and to create tools, which can help to design. This modeling could offer continuity in the design process.

We focus on the Structure-Foundation system design. So, The traditional approaches for Structure-Foundation system design are [Boissier et al 99]:

- The choice of structure is highly important. It is essential to find a solution for foundations,

- The site imposes a solution for foundations. It is then necessary to find the more adapted solution for structure,

- The choice of both structure and foundation is concerted: we have to search for a satisfactory Structure-Foundation solution.

The first approach can be explained by a late concern for foundations According to [Boissier et al 99]. In the case of soil of bad quality and insufficiently recognized, the incurred risk is the oversizing of the foundations and the overcosts that result from it. Several research works completed meet this first approach such as research works of [Toll,01]. The second and the third design approaches, contrary to the first, require an intervention before the choices for structure and foundation systems are fixed, i.e. preliminary studies. The research works that relate to the second and the third approach are very few, as works of [Sellami, 95], which relates to research a satisfactory superstructure-foundation solution for the steel constructions. So, our work is an application of the third approach without excluding the two others.

2.Objective and Limits.

Our objective is also to create an interactive tool, which will be able to define, at the early design stage and sketch creation, the orientations of the structure and foundation systems that satisfy as well as possible the client and the architect. The research of the best Structure-Foundation system requires taking into account the points of view of the other design actors (engineer and geotechnical expert). These points of view can be translated into criteria form that lead us to formulate the problem according to a multi-criteria approach of decision making.

In addition, the concerns of the client and architect are not only economical and technical; they integrate also more and more new problems such as social and environmental problems.

To formalize the decision-making process relating to our problems, we will use the approach presented in [Roy, 85]. To organize the various mechanisms of problem resolution, we will be based on the modeling process suggested by [Henry, 96] and we will adapt and supplement them if necessary.

Our approach is limited to the design of common offices building, witch are composed of reinforced concrete. The construction site must be offside earth quick area and presents a soil with horizontal and homogeneous layers. In addition, the soil data must come at least of a preliminary site investigation.

3. Problem formulation.

We schematize in figure (2) the decision-making process relating to our problem and we identify 6 tasks of this process and their sequences.

3.1. Context analysis task (task 1- box 1).

This task aims to identify the dominating constraints, which limit the project feasibility. These constraints allow defining the most adapted design approach. This task has for input the project data and for output the feasibility constraints of 1st and 2 nd levels (see later). This task consists of two sub-tasks: the soil layers qualification and feasibility's studies.

3.1.1. Project data.

This data relate primarily to the site, the parcel, the soil data, the building data (its area, its envelop kind, etc.), the desiderata and the needs of client, as well as the economic situation such the budget, the availability of the materials and equipments.

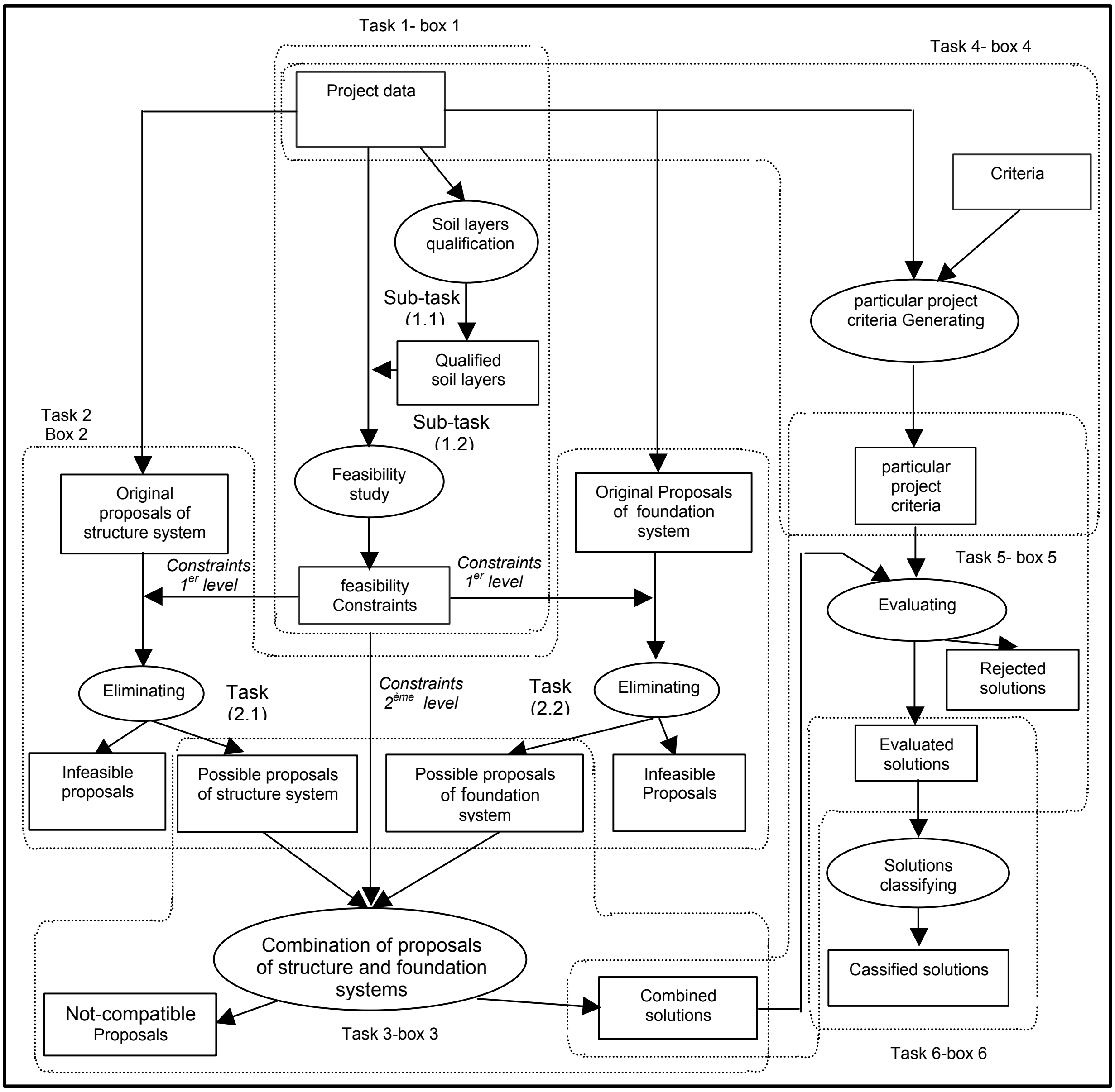

Fig. 2 : The decision-making process

3.1.2. Soil layers qualification sub-task.

The objective of this sub-task is to associate with each soil layer an indicator of geotechnical quality. This indicator allows defining the maximum acceptable loading for each type of foundation system.

3.1.3.Feasibility studies sub-task.

This sub-task aims to generate the constraints, which limit the operation feasibility. These constraints can be economics, technical and related to the site and to the time.

The feasibility studies relate to two levels: the first level takes part in the proposals eliminating task of structure and foundation systems (task 2). (Fig.2). It is characterized by the checking of feasibility of the original proposals of structure (task 2-1) before even have taken knowledge of the data of foundation and by the checking of the feasibility of the original proposals of foundation (task 2-2) before even have taken knowledge of the data of the structure. On the other hand, with the constraints of second level, which appear in 3rd and the 5th tasks of decision, the judgment of feasibility or not of one proposal depends on knowledge of the data of the two components of the building (structure, foundation). Table 1 represents some examples of 1st and 2nd levels.

		Constraints of 1st level	**Constraints of 2nd level**
Constraints applied on	**Structure**	**If** a proposal of structure has a length > length available on parcel **then** this proposal will be eliminated.	**If** the floors number in structure is higher than that supported by a system of foundation candidate **then** this combination is not acceptable. So, data of the both structure and foundation is necessary to verify the stability constraint.
Constraints applied on	**Foundations**	**If** the noise and vibration made during operation affect the surrounding area **then** the noise and vibration constraint is required. If the noise and vibration constraint is required then the foundation systems, which imply to use a noisy or vibrating technique are to be eliminated (e.g. driven piles).	**If** (the depth of good soil layer of the natural ground surface = 25m and there is not a basement in structure) **then** preformed concrete piles proposal will be eliminated because their maximum length = 20m. But, if there are two floors in basements then we can use this type of piles because piles length in this case equals to (25 - 6 = 19m). So, the feasibility decision of this foundation solution is conditioned by the knowledge of the structure data (the basements depth).

Table 1: Feasibility constraints levels (examples).

3.2.Eliminating task of structure and foundation systems proposals (task2-box2)

It consists of two sub-tasks (2.1 - 2.2). These last correspond respectively to the eliminating of infeasible proposals of structure and foundation by applying the constraints of feasibility of the first level. The task inputs are the original proposals of the structure and foundation systems as well as the feasibility constraints of the 1st level and its output is the possible proposals of the structure system and the foundation system.

3.2.1.Original proposals of structure system.

Original proposals of structure system are generated by the varying of the principal characteristics of the structure. These characteristics are: the number of floors in superstructure (from 1 to 7) the number of floors in basements (from 0 to 2) and the form of building (4 current forms with standards spans are adopted: rectangular form with a central circulation (F1), rectangular form with two central circulations (F2), square form with central patio (F3), square form with core (F4) (Moro, 2000).

Example: For a known building area = 3000 m², witch is deduced from the client needs we have 6 options of superstructure presented in table 2. In the same way, for 3 possibilities in basements reserved for the parking (floors number = 0, 1, 2) we also have 6 x3 = 18 proposals of structure. If the maximum allowed floors number in superstructure = 6 then proposals 4,5,6 will be eliminated (the remainder is 15 options).

Form	F1			F1			F2			F2			F4			F4		
Floors number in superstructure	6			7			4			5			4			5		
Width (m)	13.24			13.24			18.88			18.88			27.5			24.74		
Length (m)	38			33			40			32			27.5			24.74		
Area (m²)	3019			3058			3020			3020			3025			3050		
Basements floors number	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2
Option number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Table 2: 18 proposals of structure corresponding to a known area.

3.2.1.Original proposals of foundation system.

We adopted 9 options [Aldiab et al. 02] that result from the following possibilities: 3 foundation modes (shallow, semi-deep, deep), 2 levels of setting for the shallow and semi-deep modes, 2 shallow foundation types (footings, mat) and 4 types of deep mode (preformed concrete, driven cast-in-place, grab bored and rotary bored piles) [toll, 01].

If there is a construction, which requires calms (hospital) in the surrounding area then the noise and vibration constraint related to foundation system is required (table 1). So, the following foundation system proposals will be eliminated: preformed concrete piles and driven cast-in-place piles. There are also 7 available foundation system proposals.

3.3.Combination task (task3-box3).

This task aims to generate the combined structure-foundation proposals by checking the compatibility between the possible proposals of structure and foundation systems. The input of this task is the possible proposals of foundation and structure systems and the feasibility constraints of 2nd level. These last will allow eliminating the not-compatible proposals of structure and foundation systems. The maximum number of combined solutions=30 x9 =270.

So, we have for our example 15 x7 = 105 combined solutions. In addition, we apply the following constraint of 2nd level: If there is a fill layer of soil of an important thickness (4 m) then we have to exclude the shallow foundation systems especially when the combined solution has not a basement. So, all combined solutions that has not a basement and has a shallow foundation system must be eliminated. Concerning our example we have finally (105 - 5 x3 = 90 solutions).

3.4.Criteria generating task (task 4-box 4).

The goal of this task is to identify the particular criteria for a project. The inputs of this task are the original criteria set and the project data, which is necessary to generate the useful criteria of a project.

3.5.Evaluating task (task 5- box 5).

The objective of this task is to evaluate each combined solution by particular project criteria and rejecting the solutions too badly noted according to at least one of the criteria

3.6.Classifying task (task 6- box 6).

It aims to judge the systems, in general, via the criteria aggregation and to allow choosing.

4.Conclusion.

Currently, few tools are at the disposal of the client and the architect to control the building adaptation to the soil. In the current building case, our contribution allows to create such tools due to formulate the problem by a multi-criterion decisional approach. Moreover, it offers the possibility of concerted approach of structure-foundation systems design. To refine this approach and create a prototype a significant work is to be carried out on the criteria formalization that will have to translate the current concerns of the building actors. This work passes by the collection and systematic formalization of expertise that constitute the actual phases of our work and that will allow to develop later the three last decision tasks of our approach for an overall evaluating of several possible solutions of structure-foundation system.

5.Bibliographie.

Aldiab A. Henry E. Boulemia C. (2002) Une démarche concertée de conception de bâtiment : aide à la décision multicritère. London Conference on Decision Making in Civil and Urbain Engineering.

Boissier D., Henry E. et Boulémia C. (1999) Aide à la conception de fondations de bâtiments : un modèle d'expertise, *Revue Française de Génie Civil*, septembre 1999, Paris, pp. 267-294.

Henry E. (1996) *Pour une génération de systèmes de fondations adaptées au contexte de conception de bâtiment un modèle d'expertise pour le développement du système à base de connaissances " GENEFOND "*, thèse de doctorat, Université d'Artois. France.

Mangin J . C. (1999) *Méthodologie de conception des bâtiments*, Cours du DEA, ESIGEC.

Meniru K., Rivard H. and Bédard C. (2003), Specifications for computer-aided conceptual building design, Journal of Design Studies 24 (2003) pages 51-71

Moro, M. (2000) *Programmation des bâtiments: méthodologie et cas pratiques*, Editions Eyrolles, Paris.

PCA/PIRTTEM (1993) *Vers une amélioration des échanges d'informations entre les intervenants de l'acte de construire,* Laboratoire Génie Civil et Habitat (Université de Savoie), Méthodes et Construction (Montrouge), IRPEACS (Lyon), rapport final, subvention n° 0591-191.

Roy, B. (1985) *Méthodologie multicritères d'aide à la décision*, ECONOMICA, Paris.

Sahnouni-Belbidia Y. (1999) *Modélisation des données dans le bâtiment pour le développement d'outils d'assistance à la conception technique. Un modèle pour la simulation du cycle de la conception technique*. Thèse du doctorat, Ecole d'Architecture de Nancy. France.

Sellami M. (1995) *Optimisation et aide au choix de solutions globales fondations-superstructure en construction métallique,* Thèse du Doctorat, Université de Savoie. France.

Toll D.G. Barr R. J.(2001) A decision support system for geotechnical applications, Computer and Geotechnics Journal -28 (2001) pages: 575-590.