Analysis of the development and use of design for production in building construction – contribution for the design management

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Abstract

The adoption of ISO 9000 standards and other quality certification systems are now a reality in the Brazilian building construction and a lot of companies have obtained the certification of their quality management systems.

The investment made by those companies for the standardization of their processes, developing very complex quality management systems, is notorious. Architectural design firms, whose adhesion to the quality movement is more recent and still restricted, have followed the same tendency as the contractors. Even so, the integration of contractors' and designers' activities is neither simple nor evident, which is reflected in individual results and in those of the project.

Thus, although many actions have already been implemented for the improvement of design process, aspects observed in the site – such as execution difficulties, incompatibility of designs due to lack of integration among designers or among designers and other teams – are still hindrances for obtaining results with regard to the quality field.

The employment of design for production has been pointed out, in several surveys, as a mechanism of great potential for overcoming those barriers; even so, the achievement of this potential is questioned.

The aim of this paper is to analyse the development and use of design for production into the day-to-day of building sites, pointing out their contribution for conducting construction activities and for the integration between design and execution phases. The paper presents the benefits, difficulties and tendencies in the employment of this kind of design that was found in one case study, involving a qualified company in Sao Paulo City, stressing their importance for design process management and for the project success.

Keywords

Design for production; design process management; site management

1 Introduction

Building companies, due to the implementation of QMS (Quality Management System), underwent an "organizational adjustment", structuring themselves for the changes conceived in the building market. Reis (1998) affirms that "from the moment the implementation of QMS brought a better organization and a better understanding of the work in the organization internal sectors, attentions were focused on the design, once it is the original link of the whole productive chain, whose solutions reverberate over all the stages of the project and affect several interventions that take part in the building production process". From the points emphasized by the author, concerning the design stage, it is clear the increase of demands for design related to the needs of production in the work and which bring, in contents, rationality and economy to the construction.

The demand for elaboration of design for production aiming at the definition and the detail of certain subsystems of the building has increased and has enlarged the possibility of improving the conception and the development of the design, as well as the integration between designers and contractors (Zegarra et al, 1999). Many authors, such as Souza (1996), have emphasized the main role of design for production in solving questions that involve the adoption of a certain constructive technology, also in terms of alternatives for specification and details of the product itself, along the design elaboration, by inserting conditional factors of optimisation and buildability, to eventually present a definite production process, allowing its control and ensuring the project the desired quality.

Specialized companies are already developing the concept of design for production of several subsystems, specially masonry design. However, because of this changing process, there is concern about the correct use of these designs, so that they do not lose their original purpose, which is to meet the needs of production. It is feared that design for production becomes one more design subject and presents the same problems faced so far in the process. That is why the building company must be prepared, from a management point of view, so that the production project insertion is adequate to be properly used.

The case study presented in this paper allows to verify the main aspects related to the management of the project process in-house and to the management of the work studied itself, which directly interferes in the use of the design for production.

The benefits and the difficulties in the use of these designs will be pointed out under the builder- staff- in-the-work view. It is important to emphasize that this paper is part of the author's research, in which other companies presenting different characteristics were also studied, which made possible to outline the present reality about the use of the design for production.

2 Case Study

2.1 Methodology proposed

The methodology proposed consists in studying the several project players roles as well as the use of the design for production (DP) in building construction. Having the knowledge of the relation existing between the several DP development process players, it is necessary to define each one's attribution in the process and to identify the existing

difficulties in its use, where they may occur, and how to solve them. The following project players were thereby studied:

a) Building Company:

AIM: identifying and characterizing the design activities flow in-house and their respective players, verifying:

- The relation between the building company (design staff) x external designers, design manager x internal designers; others;
- The documentation concerning the design;
- Scope of the design for production under the building company point of view;
- The stage of decision-making concerning the DP; who is responsible for making the decisions.

METHOD USED: interviews with several process players and meetings (verification of procedures and of available documentation).

b) Design for production firm:

AIM: to verify the relation: designers x building companies; designers x site teams; designers x suppliers; to understand the DP development under the designer point of view; verifying the designer's DP scope.

METHOD USED: Interview with the designer related to the contractor. Verifying procedures, available documentation and attendance in meetings, when necessary.

c) Execution staffs (work coordinators; site engineers, subcontractors, manpower).

AIM: To analyse the work under some aspects: presentation (standardization and intelligible language), scope, detail level, ease in building up, production staff satisfaction and acceptance level, modifications occurred (why); to verify the relation: execution staffs (ES) x designers and ES x design firm manager.

METHOD USED: visit of a building company work at the design stage.

2.2 Global Analysis

Global analysis is based on some aspects especially concerning the management of the project process in the building company and management of the work. It is important to emphasize that each work will be analysed, regarding the points related to each of the players. The aspects studied are:

- Design process stage in which the design for production hiring takes place;
- Design for production feed-back for the building company design department.
- Presentation of the design for production in the site by the designer.
- Manpower training;
- Supply, storage and transportation of materials in the site.

2.3 Profile of the company studied

The company studied has acted in the real estate development and construction of buildings since 1977, having its first work concluded in 1979. It has approximately 300 employees and produces, on an average, from six to eight building projects annually, which characterizes it as a large firm. Acting essentially in the private market, it is characterized by building high- and medium-standard residential buildings, commercial and industrial buildings, as well as medium standard blocks of houses, adopting

constructive technologies such as reinforced concrete frames with ceramic masonry walls of external rendering and internal gypsum tile (except for the 1st and the last storeys).

The building company is introducing a quality management system (PBQP-H), being at present at level C i.e. the second level in this Program. The company is in process of elaborating its procedures and handbooks, and may reach certification level A by the end of 2003. It is noticed that the company has been adopting the principles of quality in its process for some time, which is observed by its directors as well. According to the company design co-ordinator, one of the reasons that led the company to seek the certification was exactly the demand for banks granting lending, which is only allowed with quality certification. According to the company development manager, the main aspect resulting from the implementation of a Quality Management System "is the standardization of all the procedures in the works, integrated with all the sectors". The company has been reaching satisfactory results with QMS because, besides improving the quality and the services, the staff feels committed to the success of the system.

Among several changes occurred with the implementation of QMS, quoted by the development manager, the possibility for the design to become one of the main tools to reach quality of the several work services is pointed out, thereby stressing its importance.

It is important to emphasize that before the implementation of QMS, , since 1994, the company has been developing an optimisation program, seeking financial, human and material resources, focusing on standardizing the production process, minimizing wastes. This program is based on four main ideas:

a) Elaboration of design for production;

b) Production technology, acting on constructive methods and techniques, as well as on materials, components, equipments and tools;

c) Organization of the production (planning, production control and organization of the building site);

d) Production management, aiming at contracts of services and administration of inputs in the building site.

This program offers the company not only sustainability to promote its technological development, but also a proper environment for implementing QMS. It is noticed that the company considers it important to use design for production for optimising production.

According to the development manager, the company "always considered the design as one of the important factors to attain quality in services", even before the implementation of QMS. The company counts on a design department represented by one design manager, two design coordinators, one designer and one trainee. The whole department is subordinated to the Technical board. Coordinators are represented by two architects whose attribution is to integrate all the designs through meetings with the designers and with the engineers responsible for the production in the site. The company acts during all the elaboration of the design and during the site works execution.

In the company design process, both the new business board linked to incorporation, and the company president, make the decisions concerning the release of a project, outlining the product as a whole. The product is defined based on a marketing research concerning typology and a series of other factors directly related to the design itself, economical viability, costs, etc. Once the profile of the new project is defined, the

architect is responsible for giving the guidelines concerning the definition of the number of storeys, type of building, including preliminary studies. Although designers of other specialties do not take part at the design stage, they give consultancy, advising the architect in the definition of parameters that help the elaboration of the design and other subsequent factors. This relationship is the result of lasting partnerships between the company and the designers of several specialties.

This design, still incipient, is sent to the company design department. The design manager sends it on to designers of some specialties, such as frames, exhaustion, hydraulics; a pre-analysis of the project is done before being sent to the municipality organisms. All the information is thereby harmonized for the design to be approved by the competent organisms. After the design approval, which originates the legal design, other designers mentioned before will be formally contracted and they will start to develop several ante designs. According to the design coordinator, three meetings for "fine-tuning" are usually held, not simultaneously, but with each project specialty separately, when adjustments are necessary. These meetings normally occur firstly when designers are hired, after the end of scheme design elaboration and after definite design conclusion. The design proceeds gradually, passing through pre-definite and, definite design, up to the final detailing.

The company does not develop designs in-house, thereby hiring all the necessary designs to the construction of the project. Besides usual designs such as architecture, structures, foundation, electric and hydraulic systems, landscape gardening, decoration, air-conditioning, among others, the company also contract designers to formwork, partitions and façades.

The first design for production used by the company was the partition design for production, seven years ago, when the company started to invest in technological development, culminating at present in the use of designs from other subsystems in the building. Before their use, the decisions concerning the work were made by the execution staff, bringing uncertainties to the process. According to the coordinator, "DP helped decrease these uncertainties". Although the company uses other modalities of design for production, this paper will analyse the partition project only, due to its importance and availability for studying it in the company.

2.4 Scope of the masonry design studied

The masonry design presented by the company is composed of the following elements:

- Location plan of partition walls, paper format A0 and on scale 1:25;
- Marking plan of 1st storey tiers, paper format A0 and on scale 1:25;
- Distribution plan of storey electric fixture, paper format A0 and on scale 1:25;
- Perforation plan of storey electric fixture, paper format Al and on scale 1:25;
- Rising plans of partition walls, paper format A4 and on scale 1:25;
- Floor plan, paper format Al and on scale 1:50.

2.5 Analysis of the studied building site

The building, whose construction started in November 2001 and which ends in the foreseen date of December 2003, presents two basements, one ground storey, one mezzanine and twenty storeys with six apartments on each floor, each apartment having 60 m2 in area. The apartments are composed of one living room and one dining room, one terrace, two bedrooms, two bathrooms, kitchen and laundry area.

The building is built of reinforced concrete frame of fcK 25 MPa, presenting slab thickness from 12 to 14 cm under foundation of open-air-large-diameter tubes. Partition masonry is made of ceramic blocks of internal gypsum lining, applied over the block (except for the 1st and the last storeys), and of external rendering and painting. At the time of the case study, the work was at the partition masonry execution stage of the 13th storey.

The organizational structure of the building site is composed of one site engineer responsible (who has been working in the company studied for 3.5 years and who has a 10-year-building-experience in other companies, especially industrial buildings), two full-time trainees, one marker (administrative), one carpentry foreman, one mason foreman and one warehouse assistant. All of them are the company own manpower. Most of the remaining manpower is hired from specialized service companies.

According to the site engineer responsible for the construction of the building, there were no delay in delivering the partition design, in comparison with the beginning of the service to be executed. After being analysed and approved, the design for production of partitions was sent out to the site by the design department. Before starting its execution, a designer representative was at the site to explain the design to the execution staff.

After the execution of the 1st storey, which works like the prototype used in industry, the main problems are identified, such as the solutions adopted concerning *buildability* and some mistakes made in the design, usually concerning modulation or adjustment to some precast piece used. These problems were noted down in the occurrence notebook and passed on to the designer who previously visited the jobsite (at the engineer's request) to analyse and identify the problems related, and who reviewed the design of the following storeys. The engineer reported that he had not taken direct part in the design elaboration stage, which only took place in the execution of the 1st storey.

The development manager emphasizes that the implementation of the design for production on the 1st storey is done little by little, by verifying if the execution staff is getting familiarized to the design. Thereby, first the masonry location plan is verified before its execution and the main difficulties are remarked. Second, the marking plan is checked and so on, until the execution of the 1st storey is complete. Because of this process, the execution of the 1st storey usually takes longer than the other subsequent storeys, which allows the manpower to get used to the masonry design. Only at this moment is the designer asked to visit the site because, according to the development manager, the designer's visit is onerous.

The masonry design for production analysed shows a great deal of pre-casted pieces (about nineteen) and blocks of several thicknesses and lengths to be compatible with the horizontal and vertical modulation of the design, according to specification of the elevation notebook. To see to the demand of the pre-casted pieces of the design, a manufacturing station was installed on the basement. To manufacture these pieces, the following materials are necessary: metallic moulds and concrete made of one 18-liter can of cement, 1 ½ 18-liter can of sand and 1 can of crushed stone. According to the worker responsible for manufacturing these pieces, the amount of water used was enough to produce a mixture of granular and dry aspect, which can be easily compacted. Compaction is done using a hammer over a thin piece of wood directly over the piece.

A non-qualified worker of the company is responsible for manufacturing these pieces in the manufacturing station. To ensure that, the trainee of engineer gave him initial instructions about the manufacture of these pieces, instructions about the composition

and the amount of each piece per storey. About 50 pieces are made daily, depending on the type, but this amount may decrease to 24 in case of more complicated pieces. The responsible reported that the pieces are used 24 hours after manufacturing, because they are widely used. No specific control of these pieces was verified in the manufacturing station. According to one of the contractors responsible for masonry execution, the contractors themselves usually request the manufacturing of certain pieces in the manufacturing station and there were moments when work had to be stopped, due to the lack of certain pieces.

The blocks furnished are stored on the ground floor over pallets, forming 10 piles on the whole, maintaining their physical integrity. The identification of the blocks was verified according to their thickness and length, in an easy-access place in order to transport them to the crane. Pallet carrier cars and a crane transport the blocks from the stock place until the execution storey, through horizontal and vertical transportation, respectively. Blocks are located according to the execution staffs localization.

The materials used to manufacture mortar are transported to this floor in sacks containing the predetermined amounts, according to specification of the composition by the development manager. Cement is packed on the ground floor in amounts of 8 kg to masonry. Sand is packed on the basement in amounts of 33 kg and lime is furnished in sacks of 5,5 kg. These materials go to the basement where mortar is manufactured at the rate of two 33-kg sacks of sand, a sack of lime (according to supplier standard) and an 8-kg sack of cement . According to the engineer responsible for the construction of the building, there were no delays in delivering ceramic blocks that could endanger the masonry execution process. One of the contractors related that the lack of a certain block did not endanger masonry, but there were moments when it was necessary to change the specification of the design concerning the thickness of the wall, due to delays in delivering blocks. For example, the design specified the need of blocks for 14-cm walls, but in the site there were only blocks of 11,5 cm and these were used instead of the specified ones.

An agreement was verified between the company and the suppliers, the result of a lasting partnership, according to the development manager. One of the attributions of the company development department is to search for suppliers whose products can meet the requirements of the standards of quality and performance expected and that can ensure the continuance of supplies. The development manager reported that, when the rationalization program was introduced in the company, in 1994, they were initially searching for improving the aesthetic aspect of masonry. Thereby, many problems involving cracks and fissures were found, which encouraged the company to analyse the performance of the masonry and the criteria to be adopted in the specification of materials, in order to execute them properly. Thereby, there were concerns not only about aesthetic aspects, but also about the performance of the materials used and final masonry. Several essays with blocks and mortar from the main suppliers were performed in order to establish partnerships with those who could supply products that could ensure the performance of masonry. The development manger said that the resistance to the compression of the partition blocks used reaches 8,5 MPa. Specific pattern values register a least of 2,5 MPa, but according to him, this value is not enough to ensure a satisfactory performance of masonry.

The manpower used for executing masonry in the work studied is subcontracted from two different companies. The contractor company E1 (CC1), has been acting in the building market for four years, rendering services to the company such as masonry,

revetment and services in general. The staff is composed of 25 workmen, six of them are masons and two of them are workers who are subcontracted. There was no specific training of the execution staff by specialized companies. The company itself offered this training, through the reading of the company masonry execution procedures by the trainee, who explains the main points, and through orientation during the execution of masonry on the 1st storey. The contractor reported there was initial difficulty in the use of design for production because of the staff little experience with masonry, which occurred because he dispensed with the previous staff (which was used to the design), due to lack of work in the company during a period of six months. The main difficulties concerning manpower, according to the contractor, were: initial resistance concerning the use of masonry design, great amount of blocks and pre-casted used, which disturbed the productivity in the execution of the first three storeys, difficulties to read the design for not being used to it, and disqualified manpower. The contractor emphasizes that masonry design considerably improved the final quality, the esthetical aspect as well as helping decrease pathologies such as fissures, once it is designed to reach better performances. He reported that cleanness in the storey improved a lot, because it is necessary to let it free for the installation of masonry. He emphasized that the design demands manpower to be much more qualified than in the past, because now manpower needs to execute masonry as well as interpret the design. According to him, “anyone in the past could build a wall; all you had to do was to put mortar and blocks respectively, and in the end, according to the space left, you broke the blocks, and there was not the use of screens”. “When manpower is correctly trained, the design simplifies the execution of masonry”.

The contractor company E2 (CC2) has been acting in the building market in Sao Paulo since 1995. It began executing other services in the company. It has a staff composed of 28 employees, eight of them are masons and three of them are mason trainees. This is its first masonry work executed for the company. The contractor reported that it has already executed masonry without design for production in other companies and he observed a considerable difference in its final quality. He added that the use of design does not allow improvising constantly and it makes clear which must be its final aspect, besides making the execution of masonry stage by stage easy, through location and marking plans and through the rising plans.

According to the engineer, to the contractors and to the manpower itself, some problems were pointed out, involving management of the work and insertion of the masonry design for production:

- One pre-casted piece specified in the design could not be adjusted to the modulation of masonry, which establishes its cut along the execution. After the execution of masonry on the 1st storey, there was a change in the design so that the angle of the piece could be adjusted to the concerning wall;
- Manpower was not properly executing the distribution of joints of the horizontal modulation, which caused the blocks to break in the final adjustment of the wall. The design foresees some adjustment joints which must be observed during execution;
- The blocks in the connection of walls with columns were not being properly compressed, causing adherence between interfaces. This fact was observed by the engineer, who pointed out a failure in execution: the blocks of the middle of the tier were being adjusted prior to the blocks of the edge. This fact occurs,

according to him, due to execution staff's inexperience and unfamiliarity with procedures and with the company system;

- Difficulty in mooring blocks in the connection of walls;
- Some walls presented problems in plumbing, causing the collapse of a wall;
- Some masons had difficulty in keeping the thickness specified in the design to fix masonry to the beam or to the slab (2 to 3 cm), causing the withdrawal of the last tier to put another type of block, differing from what had been foreseen;
- Dirt on the execution floor. The company demands cleanness in the execution of its works;
- Some types of blocks were substituted in the adjustment by others that were not specific to a certain tier due to its lack in the building site, at the moment of the execution. This fact occurred so that the work process was not damaged. According to the engineer, there was little occurrence of this fact;
- One wall had a fissure in the connection with the column, in all the floors. This fact was reported to the structural designer, to the development manager and to the masonry designer, who held several meetings to discuss the problem. According to the development manager, it is believed that it may be a problem of deformation of the slab, (confirmed by the designer of structures himself) whose dimensioning was made difficult by the architectonic party option in which the slab of the storey presented a very marked unevenness;
- One wall was identified consisting of location and marking plans, however it was not noted down on the rising plans and it had to be adapted in the jobsite;
- The unevenness verified in the storey, according to the architectonic option and the definition of only one longitudinal axle, made the installation of masonry difficult in the places where this unevenness jutted out;
- Workers reported that some little adaptations were made in some walls, such as: installation of compensating blocks, when it was not specified in the project, so that the joint would not present a very prominent thickness; breakage of blocks in the last tier to promote the passage of electrical circuits (the project does not foresee it);
- The wall presented rips after the passage of hydraulic pipelines. The masonry project does not foresee the interference of hydraulics in the wall. According to the development manager, this is a problem to be solved. At least, optimisation is done ripping the wall with an electric cutter.

It is emphasized that many of the problems concerning the execution of masonry, especially concerning manpower, were minimized from the execution of the third storey on, when workers were familiarized with the design.

According to the site engineer, technical meetings with the board are held monthly to discuss problems about the work studied, main difficulties and solutions adopted to solve these problems. Besides the meetings, the engineer provides a written report of non-conformities, when the work is being concluded, which is sent out to the development manager and to the project department.

Concerning his opinion, the main benefits obtained with the use of design for production are: better quality in execution, improvement in quality control, improvement in productivity when the staff is properly qualified and trained, optimisation of materials and decreased waste.

3 Conclusion

The use of design for production for several elements of buildings is a reality incorporated in the state of Sao Paulo. The benefits of their use have been verified, pointed out especially by the execution teams, emphasizing the decrease in uncertainties and in decisions made in the building site, increase in productivity and in quality of the service executed.

Building companies must be prepared from the management of its suppliers as a whole, whatever it involves manpower, construction materials or design, so that the insertion of the design for production takes place properly, attaining the purpose to which it was conceived: simplifying the production process.

4 References

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