STABILIZATION AND STANDARDIZATION OF A PRECAST PRODUCTION PROCESS

Carlos Antonio Samaniego Gallardo[1], Ariovaldo Denis Granja[2], Flavio Augusto Picchi[3] and Alex Tort Folch [4]

ABSTRACT

Adapting and implementing new management techniques based on principles and tools originated in the manufacturing industry have been challenging the construction industry. This research aims to present improvements achieved in the fabrication process of precast concrete roof tiles, after a first stage of diagnosis and basic stabilization of the production process. This work was carried out jointly with a Brazilian company in the state of Sao Paulo, dedicated to the erection and fabrication of pre-cast concrete components. This study is part of an ongoing action-research, where the production process of concrete precast roof tiles fabrication was already analyzed. After a first diagnosis of the production process, lean principles and tools were used to stabilize and standardize the production process of these precast components. Results allow concluding that lean implementations helped with the basic stabilization and standardization of the different work elements involved in the fabrication system of precast concrete roof tiles and could be adapted to other precast concrete components production process, providing higher reliability in the production process and production throughput improvements for these components.

KEY WORDS

Precast, roof tiles, stabilization, standardization, production processes.

[1] Civil Eng., M. Sc. Candidate at GTE/Unicamp, carlosasamaniego@yahoo.com

[2] Ass. Professor, Construction Management and Technology Research Group (GTE), School of Civil Engineering, Architecture and urban Design, Department of Architecture and Building, State University of Campinas (UNICAMP), Avenida Albert Einstein, 951, Caixa Postal 6021, Campinas/SP, CEP 13083-852, Brazil, Tel.: +55 19 3788-2082, FAX + 55 19 3788-2411, adgranja@fec.unicamp.br, fpicchi@fec.unicamp.br

[3] Ass. Professor, Construction Management and Technology Research Group (GTE), School of Civil Engineering, Architecture and urban Design, Department of Architecture and Building, State University of Campinas (UNICAMP). Director, Lean Institute Brasil, Rua Topázio 911, São Paulo/SP, Brazil, CEP 04105-063, Tel.: +55 11 5571-6887, FAX: +55 11 5571-0804, fpicchi@lean.org.br

[4] Civil Eng., Technology and Quality Director, MUNTE Industrialized Constructions, Ltda. , atf@munte.com.br

INTRODUCTION

The implementation of new administration techniques in civil construction has become a key element in the development of this area, and the use of the manufacturing industry as a key reference to achieve this has grown throughout the years (Koskela, 1992).

The successful evolution of the manufacturing industry, starting with the Mass Production all the way to Lean Thinking, was originated not only because of their ability to standardize its components, but also to be able to standardize the administration and production processes in the production line (Womack *et* al., 1992).

This research aims to illustrate the improvements achieved in the precast concrete roof tiles production process, through the interface of the involved process stages using a number of Lean principles and tools as reference (Picchi, 2003), where the high level of industrialization of the process allows an easier adaptation and a better example of the lean principles and tools application. Previous studies present analyses of projects involving precast components, management and the manufacturing process as well, showing improvements in the application of lean production principles and tools creating a good baseline for other studies (Ballard et al., 2003; Sacks et al., 2004). In this specific case they were used to reach a basic stability in the production process, and in a second phase to reach a basic standardization of the work elements' sequences.

In order to achieve these goals, the present study posed the question on how to achieve the basic stabilization and standardization of the work elements[5] involved in the production process of precast concrete roof tiles[6], by analyzing the production sequence and rearranging the work elements involved in the production of these components. This basic stability and standardization are necessary in order to proceed in any other stage in a lean process. Most previous studies on the subject have as a baseline that the production process is stable and has been standardized, allowing them to analyze the production process as a whole (Ballard; Mathews, 2004).

STABILIZATION AND STANDARDIZATION BASED ON LEAN THINKING

The success of mass production and afterwards of lean production was not their ability to produce a great amount of products, but the ability to standardize the production stages and work elements. One of the main characteristics of lean production is its ability to produce a high variety of products in a great amount and in a lower time, that is flexibility in the production process that doesn't interfere with the expected productivity (Shingo, 1996). Based on this fact, lean thinking offers a great amount of tools that allows reaching standardization (Womack et al, 1992). Inside the civil construction industry, the criteria used to standardize the processes has not reached a consensus. Besides, it is not possible to standardize all the activities and work elements, but only the more representative in each activity (Maia, 1996). On the other hand it's not possible to reach the standardization without a basic stability, and not only in the number of pieces to be produced but also in the production sequence and lead times. Based on that, the first thing to do before standardization is to stabilize the production system (Womack; Jones, 2004).

[5] "The smallest work increase that could be transfer to another person" (Rother; Harris, 2002)

[6] In this research 'roof tiles' refers to precast prestressed beams use to cover the building; they have an approximate length of 15 meters, depending on the design.

For this purpose, Lean Thinking has a great variety of tools that could be of great help to reach the basic stability and standardization of the processes. Among them we can mention:

Value Stream Mapping (VSM)

VSM is a key tool for the analysis of any process, being an effective technique to visualize the way that processes function as a whole or each one separated, besides that this tool allows to identify different types of waste in the processes. This tool has as a second stage the design of a future state map where tools and principles of lean thinking are situated in specific stages of the process so wastes in the process analyzed could be reduced or eliminated, thus improving it (Rother; Shook, 2002).

Operator Balance Chart (OBC)

The balance of the production has as main target to create stability between the previous process stage and the next one, allowing a continuous flow in the production (Shingo, 1996). Using this as a premise, the OBC presents a great utility in the distribution of the operators involved in processes with multiple stages, allowing the creation of continuous flow in the process, and distribution of the tasks based on the takt time (Lean Enterprise Institute, 2003).

Andon

In the lean production vision of quality a key element is to identify and correct the problems as soon as they appear, so they can not advance in the production line and don't happen again (Liker, 2004). For this purpose, the main tool used by lean thinking is the *Andon*, a tool of visual control in the "work area". This tool allows visualizing anomalies in the production as for example: production status, quality anomalies, machinery set up, machinery stops, etc. We can find mainly two types of *Andon*: Alert *Andon*, which indicates any type of problem or failure in the production process, and Status *Andon*, which shows the actual stage of the production. This type of *Andon* is used to illustrate the production status, by comparing the number of pieces to be produced (plan) and the number of pieces produced (real) and helps to point out in real time where the anomaly is and the probable root causes (Lean Enterprise Institute, 2003). This allows the person in charge to be aware of the delays, problems and possible solutions in real time, avoiding future interferences in the production lines maintaining a continuous flow (Shingo, 1996).

RESEARCH METHOD

The research was initiated in August 2005 and was divided in three main stages. The first stage is called initial evaluation. The second stage is called stabilization and evaluation. In this stage there was noticeable interaction between the researcher and the employees in charge of the areas involved. In the last stage of the research, a basic standardization of the sequence and time schedule of the work elements was achieved, and also an evaluation of all the advances in the factory was done. It's important to mention that the researchers are still working on this last stage.

The partner chosen for this research, Munte Industrialized Constructions Ltda., has been established in the civil construction industry since 1975, mainly dedicated to the fabrication and erection of precast concrete components, possessing ISO 9001-2000 certification since 2002.

The study was carried out in the factory located in the district of Itapevi, São Paulo, Brazil. This factory is dedicated to the fabrication of several families of precast components. The present study was concentrated in the production process of one family of precast component: the roof tiles. This family of components were produced in two production tracks, having as average daily production, six roof tiles per track, in which the different work teams: steel (knotting) team, pre-stressing team, concrete team and general helpers, work in both tracks in the different work elements involved in each stage of the production process, executing work elements in sequence and sometimes overlapping different work elements or tracks. It's important to mention that by December 2005 a third roof tile production track was devised, increasing the number of components produced each day. By the time of this production increase, the number of employees was increased by three helpers only. By the time the study began, this product family layout was already modified, besides several modifications based on 5 "S" practice and value stream mapping, which allowed a higher possibility of success in the application of the tools and implementation of the lean production principles, to reach the basic stability and standardization.

RESULTS

Work elements classification

Initially the classification of the work elements involved in the production process of roof tiles was achieved through a meeting at the factory floor with the person in charge of the production of this product where he explained in a general way the sequence in which the work elements involved were carried out and the different general stages of the roof tiles production process as well.

In a second stage after this meeting, the researcher observed during several days the production process obtaining data and classifying the different stages observed, and the work elements involved in each one as well. Based on these observations and the data obtained, the production process stages and work elements involved in each one were classified.

VSM evaluation

The company had already designed an actual and future state VSM, after an improvement cycle that had been implemented in the factory, having achieved several goals of the future state VSM, as for example, creating continuous flow between some stages, and eliminating some stocks by creating supermarkets, among others.

Achieving these goals before the beginning of this research, allowed a better implementation of the principles and tools in the next stage of research. For this reason, at the time that the actual state VSM was devised (Figure 1), most of the waste was already eliminated, with the result that the VSM designed in this research did not reach some of its goals, as for example, representing explicitly the interposition between the work elements, but at the same time it allowed visualization of the variations in the number of workers involved in each team in each work element as the oscillation in the stages durations.

Besides trying to implement the future state VSM, a more detailed analysis of each work element was needed in the interaction between them, a reason that led us to propose the design of an OBC of the work elements of the activities involved.

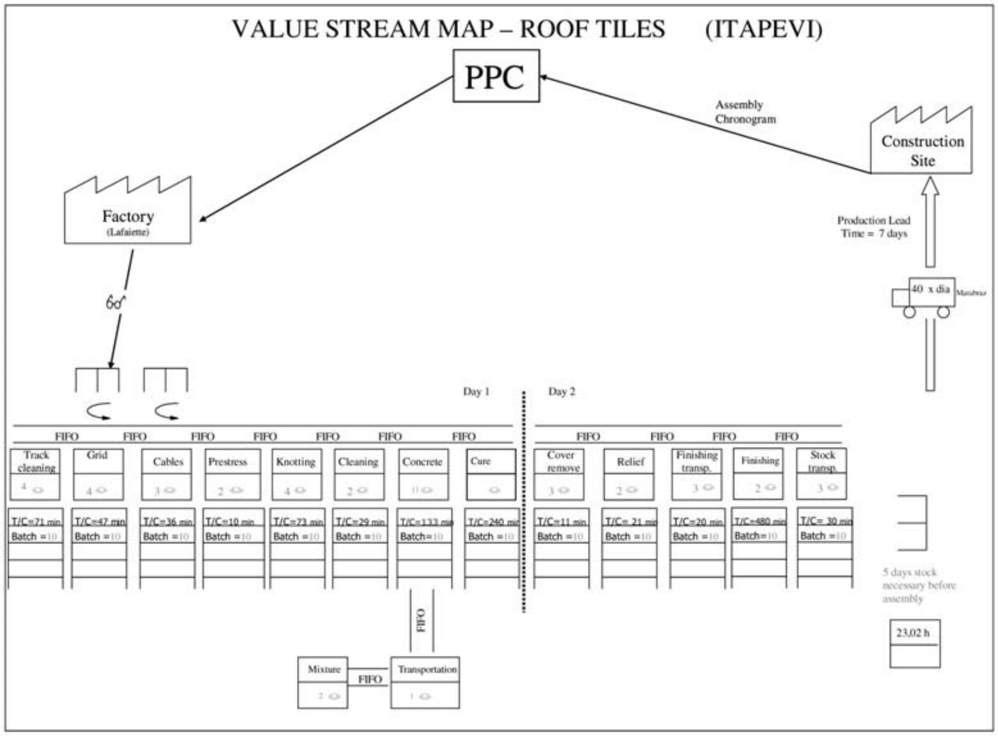


Figure 1. Initial Stream value map

Operator Balance chart (OBC) Diagnosis

By analyzing the OBC of the work elements involved, variations in the production times of the different work elements could be identified, as well in their general sequence, demonstrating the lack of basic stability in the production's process.

This fact pointed out the necessity of applying the lean thinking principles and tools to reach a basic stability in the production process so that in the next stage it would be possible to establish a basic standardization.

Basic stabilization: Production Status *Andon*

In order to stabilize the work elements production schedule, a Production Status *Andon* was devised (Figure 2) based on the execution time of the different stages already analyzed and their respective time schedules established jointly in meetings with the person in charge of the production of these components. The first proposal was changed several times during the research, based on the dialog between the researcher and the persons in charge of the production. The number of work elements to be analyzed was increased, since some of them were considered critical to have better control points of the production's process.

After several days of collecting data, it was noticeable that some of the data didn't match with the time schedule planned. Based on the data of the *Andon* it was detected that one of the reasons for this problem, was the variability in the number of persons in each team. To solve this, the addition of a column in the *Andon* was proposed, which would indicate the number of persons involved in each team, in this column the person in charge would register any changes in this matter, besides a possible solution so this did not happen again. This cycle of specific changes in the planned time schedules and the number of persons involved in each team was maintained during several weeks until an almost perfect match between the time schedule planned and the real one was achieved.

Figure 2 shows the last modified Andon, where it illustrates the final classification of the work elements considered as critical to have a better control between the production sequences as its stability. In this Andon the third roof tile production's track was already considered, And at the right end of the figure, it can be noticed the column of "Observation", that was one of the key elements for the success of the Andon, since in this column the problems in each stage and possible solutions and improvement suggestions were registered, that allowed identification of the main causes of the delays in the daily production in real time, and helped to maintain a continuous improvement cycle in the production process.

LOCAL: ITAPEVI		Daily production: Track 1					DATE: / /
Process stages	Work elements	NUMBER OF WORKERS	START		FINISH		Observations
			PLAN	Real	PLAN	Real	
Stress relief	Stress Relief	10	6:10		6:50		
Finishing area transport	Unforming and transportation	5	7:00		7:20		
Final Finishing	Sandwork and finishing	3	8:30		11:00		
Track cleaning - grid location - prestress preparation	Unforming cleaning - Grid placing - Prestress preparation	6	7:10		9:15		
Prestress	Prestressing process	2	9:20		9:35		
Grid knotting	Grid knotting and steel knotting after prestress	6	9:35		11:30		
Concrete	Concrete (car movement)	14	12:30		13:40		
	Finishing team	6	12:50		14:00		
Stock area transport	Day before roof tiles transportation	5	16:55		17:20		

Figure 2: Production Status Andon.

Results of the basic stabilization

After a series of changes in the time schedule and classification of the activities, as in the definition inside each process, an almost complete basic stabilization in the roof tile production process was achieved.

In Figure 3 the Percentage of Time Schedule Accomplish Based on Plan (PTSABP) is shown, this being an index created to identify during this research the differences between the time schedule planned and the actual ones. Figure 3 shows data proceeding from an *Andon* based on the agreement between the researcher and the person in charge of the production's process of these family components. This index was crucial to evaluate the degree of stability of the production process and also important to evaluate the problems and possible solutions required to achieve this stability.

At the beginning of the implementation of the *Andon*, the real time schedule matched about 30 per cent of the times with the planned time schedule, but after all the changes and improvements were made to the initial *Andon*, it was possible to achieve a match between the baseline plan and the actual, around 75 per cent of the times, with a rising PTSABP tendency and in some occasions reaching 100 per cent. It's important to mention that most of the variations in the graphic tendency occurred due to external agents, such as rain and broken equipment.

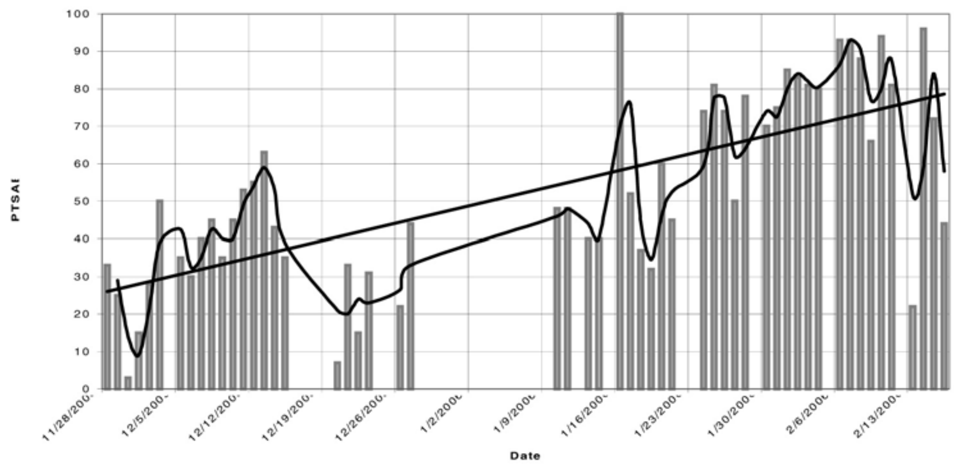


Figure 3: Percentage of Time Schedule Accomplish Based on Plan (PTSABP).

During the different stages involved in this research, an increase in the productivity of this production's process was noticed during implementation, reaching a reduction in the number of man hours per cubic meter produced, from 21 to 16, as is shown in Figure 4.

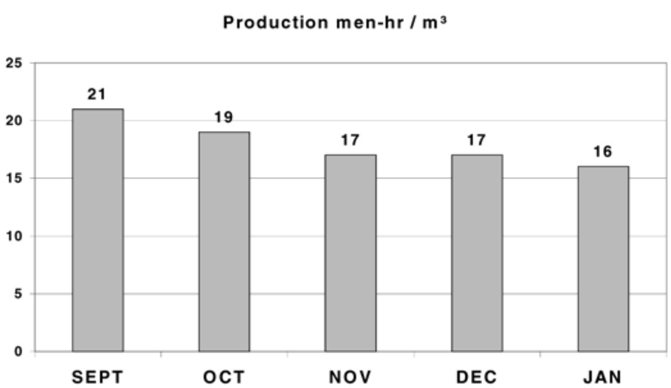
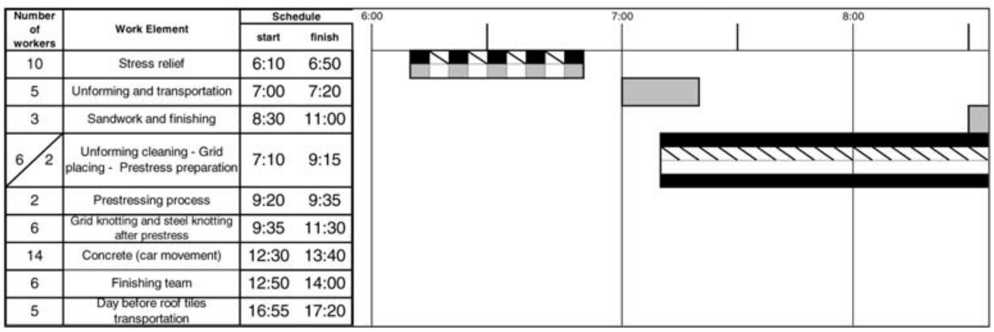


Figure 4: Roof tiles productivity increase.

Basic Standardization

After reaching the basic stabilization of the production process, the standardization occurs almost by itself, requiring only the formalization of the work standard that was going to be used in the three production tracks. Some of these worthy of mention: team organization, specific team working areas during the day and the time schedule of the activities involved.

Figure 5 shows a glance at the Standardized Work Combination Table of the roof tiles production process of one of the production tracks, which was modified for this specific research, where the bar instead of representing each operator, represents each of the teams involved during the day, in each one of the work elements.



Number of workers	Work Element	Schedule start	Schedule finish
10	Stress relief	6:10	6:50
5	Unforming and transportation	7:00	7:20
3	Sandwork and finishing	8:30	11:00
6 / 2	Unforming cleaning - Grid placing - Prestress preparation	7:10	9:15
2	Prestressing process	9:20	9:35
6	Grid knotting and steel knotting after prestress	9:35	11:30
14	Concrete (car movement)	12:30	13:40
6	Finishing team	12:50	14:00
5	Day before roof tiles transportation	16:55	17:20

Figure 5: Standardized Work Combination Table of roof tiles production work elements.

CONCLUSIONS

Despite the fact that the VSM tool didn't reach its goal completely in this specific case since improvements were already accomplished, it was possible to identify and visualize the process as a whole. These facts guide us to the utilization of another key tool in this research, the OBC, allowing us to visualize in a more detailed way the different variations in the real time schedule, as in the sequences of the activities involved in the production process.

The analysis of the work elements using these tools facilitated the implementation of the Production Status *Andon*, leading to achievement of the goal of the basic stability, and as result a basic standardization. Both are identified as basic elements for the implementation of the lean production principles and tools.

Among the problems that appeared at the beginning of the research, it's worth mentioning that the biggest one was the operators' organization. Problems such as lack of material, equipment or operators, rarely occurred. Once the operators' organization was defined, with their daily task and schedule, the delays in the production sequence were caused only by external parameters such as rain and broken machinery. This is shown in the PTSABP graphic (Figure 3) where values of PTSABP below 75% occurred because of the external causes mentioned before.

The use of lean production principles and tools in the civil construction industry could bring great benefits in the production's process. In the case analyzed, the principles and tools allowed reaching a basic stability and as a result a basic standardization, which is one of the keys for the success of lean implementations.

The "analysis – implementation – evaluation" cycle, traditional in action-research, allowed structuring the research and developing a more participative role regarding operator's involvement. This cycle also helped point out to people involved the importance and benefits of the stabilization and standardization of work's elements in the production cycle.

Studies of the application of this implementation cycle in other precast family products are part of an ongoing research in this factory, where the tools and analysis sequences detailed in this article have been used successfully. The authors recommend studies of basic stability and standardization in other production areas in the civil construction industry, since this could be valuable to consolidate the implementation of lean principles and tools in the sector.

ACKNOWLEDGEMENTS

We are indebted to Munte Industrialized Constructions Ltda., specially to the people in charge for the production of the roof tiles elements, Lafaiete and his assistant Reginaldo for all their collaboration, and to all the operators of the Itapevi factory who cooperate with this research.

REFERENCES

Ballard, G.; Mathews, O. (2004). "Prefabrication & Assembly". White Paper in: *Proceedings of the 12th annual conference of the International Group for Lean Construction*. Elsinore, Denmark. (available at http://cic.vtt.fi/lean/conferences.htm.)

Ballard, G.; Harper, N. and Zabelle, T. (2003). "Learning to see work flow: An application of lean concepts to precast concrete fabrication." *Engineering, construction and architectural management*, v. 10, n. 1, p. 6-14, 2003.

Lean Enterprise Institute. (2003). *Lean Lexicon: a graphical glossary for lean thinkers*. 2 ed. Lean Enterprise Institute. U.S.A.. 102 pp.

Liker, J. K. (2004). *The Toyota Way. 14 Management principles from the world's greatest manufacturer*. 1 ed. McGraw-Hill. United States of America. 330 pp.

Maia, M.A. M. (1996). "Organização do trabalho a partir da padronização da produção de edifícios". (Building's production standardization for organization of work) *Anais do Congresso Técnico - Cientifico de Engenharia Civil. Florianópolis*. Brazil p. 174-179.

Picchi, F. (2003). "Oportunidades da aplicação do lean thinking na construção" (Opportunities of application of lean thinking in the construction industry)". *Revista Ambiente Construído*. 1 (3). Fortaleza, Brazil. p. 7-23.

Rother, M. ; Harris, R. (2002). *Creating continuous flow*. 1 ed. Lean Enterprise Institute. U.S.A. . 104 pp.

Rother, M. ; Shook, J. (2002). *Learning to see*. 1 ed. Lean Enterprise Institute. U.S.A..112 pp,

Sacks, R.; Eastman, C. M. and Lee, G. (2004). "Process model perspectives on management and engineering procedures in the precast/prestressed concrete industry." *Journal of Construction Engineering and Management*, v. 130, n. 2, p. 206-215, Mar./Apr. 2004.

Shingo, S. (1996). *A study of the Toyota production system*. 2 ed. Productivity Press. U.S.A.. 291 pp.

Womack, J. P. ; Jones, D. T. (2004). *Lean thinking: banish waste and create wealth in your corporation*. 2 ed. Simon & Schuster. U.S.A.. 397 pp.

Womack, J. P. ; Jones, D. T. and Ross, D. (1992). *The machine that change the world*. 1 ed. Harper Perennials. NY, U.S.A. 323 pp.